INTRODUCTION AND STATEMENT OF PROBLEM

The data supporting this study were obtained by means of the Bergström Ergograph.[1] The well known unavoidable defects common to ergographic work are of immaterial value here except as they may exert a preponderating accidental influence in either the known or unknown series of experiments.[2] The long period of time over which the experiments extended would tend toward an equitable distribution of such defects and iron out any irregularity of emphasis to one or the other of the series.

The question of distribution applies to such defects as physiological variations and to mechanical variations of the machine such as leverage and adjustment. As to variations in the mental complex with reference to such features as attention and content there are wide differences according to whether the observer is fully or partially aware of his progress. The factor of tediousness must also be considered. However, the question of attentive fluctuation or tediousness, as it may relate to the degree of volitional innervation, may arise with reference to any work period of any series (known or unknown) of periods all conducted under constant conditions.

In the periods of a *known* series, i.e., where the observer is fully aware of his efficiency, attention and tediousness vary widely from the periods of an *unknown* series as is expected. In the former series, attention is heightened and tediousness lessened; in the latter series, especially in the initial work periods attention frequently lags and a certain ennui marked by a distinct feeling of depression often pervades the entire series. This is especially true of the periods in the series of the first set of experiments. In any series of work periods, the periods *inter se* proceed under varying degrees of attentiveness and interest. Since the efficien-

[1] This apparatus, which is not very simple, is described at length by Prof. Bergström in the Amer. Journ. of Psychology, Vol. XIV, 1903, pp. 510-540.

[2] T. Hough: Ergographic Studies in Neuro-Muscular Fatigue. Amer. Journ. of Psych., Vol. 5, 1901.

cies of work periods within a given series are not compared but rather the efficiencies of periods of different series, such attentive fluctuations can not for our purpose be considered defects. As far as variations in attention and tediousness apply to work periods of disparate series (i.e., known and unknown), we find in them conditions accounting for efficiency differences.

The question concerning which an experimental answer is here attempted is, whether a condition of relatively complete awareness of results is more or less favorable to efficiency than is a condition of partial awareness. To what extent, if any, does knowledge of results further efficiency; or, to what extent does a lack of knowledge curtail efficiency; or, is the aggregate accomplishment indifferent to differing degrees of conscious accompaniments. Again, is a response, in which a knowledge of results constitutes essential features, more or less efficient than a response when such knowledge is relatively lacking.

The work of Judd[3] on "Practice without Knowledge of Results" clearly permits the conclusion that greater efficiency results when the observer is aware of the conditions underlying the procedure of the experiment. It is probable that still greater efficiency would have resulted had the subjects observed by how much their reactions were in error.

Conduct of the Experiment and Attending Considerations

The data finally incorporated in this study were preceded by an unusually long period of preliminary practice. The entire period of experimentation, in the case of observer M, covers three years, two of which suffered certain unavoidable interruptions. The results of these two years are not included in this study and their chief value lies in the fact that practice effects reached a desirable minimum. The data, therefore, represent the efficiency values of trained muscles. In the cases of observers, J, and W, so extended a preliminary practice period does not obtain. All experiments were begun at approximately 9 A. M.

The hand and arm of the observers were strapped into the ergograph in the usual manner so as to secure maximum free-

[3] Psychological Rev., Monog. Supp., Vol. 11, 1905.

dom for the middle finger of the right hand and to exclude, so far as possible, all irrelevant movements contributory to the efficiency of this finger.

The study is divided into three sets of experiments; each set is divided into four series: ascending and descending known[4] and ascending and descending unknown. Each series of the first and second set is divided into work periods of eleven each. The known series consists of experiments in which the observer was fully aware of his results during the conduct of the experiment and of his results during previous known work periods. The records of the known periods were at all times open to the observer's critical examination; the records for the unknown periods were closed for the observer during, as well as after, the completion of an experiment. Both the known and unknown series consist of work periods made up of subdivisions each of which has a constant duration of ten seconds excepting the periods in which there are no rests. The rest between each of the subdivisions of the periods, common to the two series, varies from zero to ten seconds. Eleven work periods, each separated by an interval of forty-eight hours, constitute a series in which there is continuous work in the zero period; a rest of one second to every ten seconds of work in the first period; two seconds of rest to every ten seconds of work in the second period and so on until the seconds of rest equal the seconds of work, i.e., ten. It will be noticed that in the ascending known and unknown series of the first set and in the ascending unknown and known of the second set the number of rest seconds for each subdivision of the work periods of the series forms an arithmetical progression by a common difference of 'one' from zero rest in the zero work period to ten rests in the eleventh period. The corresponding decreasing series of the first and second sets form a descending

[4] Note: The terms 'ascending' and 'descending' apply to the order in which the work periods of a series are performed with respect to an increase (ascending) or decrease (descending) in the number of rests of successive periods.

The terms 'known' and 'unknown' will always refer to the observer's knowledge or lack of knowledge respectively of his efficiency.

arithmetical progression by the same difference with respect to the number of rests.

The work in each period is continued to exhaustion, i.e., until the observer is no longer able to lift the ergographic load. The observers were instructed to make each effort, that is each lift, represent maximum voluntary contraction. Since the periods always continued to exhaustion it was desirable to extend the duration of the interval between periods—forty-eight hours—to permit of relatively complete restoration of the tissues and to avoid soreness. In each subdivision of the work periods the second failure to lift the load was the signal to stop the experiment. The muscle was then regarded as exhausted, and by this it should not be inferred that we hold it possible to extract the last item of movement by means of voluntary innervation.[5] The speed of lifting was fixed by a metronome beating sixty strokes to the minute. In the zero period work is uninterrupted by rest; in the first period ten seconds of work (i.e., ten lifts) alternate with one second of rest; in the second period ten seconds of work alternate with two seconds of rest and so on, as already indicated, until the seconds of work and rest are equal. Algebraically this may be represented by the formula $\frac{P}{W + R_0}$, $\frac{P}{W + R_1}$, $\frac{P}{W + R_2}$, - - - - - - - - $\frac{P}{W + R_{10}}$, in which P = work period in in which each subdivision represents ten ergographic lifts; $W + R_0 =$ no rests between subdivisions; $W + R_1 = 1''$ rest between subdivisions and so on to $W + R_{10} = 10''$ rest between subdivisions. This procedure applies equally to the known and unknown series of experiments.

Excepting the third set of experiments, each set comprises four series (two known and two unknown) and each series comprises eleven subdivided work periods. The third set differs from

[5] 'Exhaustion' as here used means nothing more than that the ergographic load could not be budged for two successive attempts; it certainly does not imply an anaesthetic condition of any part of the neuro-muscular chain. Moreover, it is doubtful whether anything like exhaustion is possible through voluntary stimulation.

the first and second in the sequence of the series, in the load, and in that the work periods number six. The first and second sets differ only in the sequence of the series.

First Set

	I→	
First Known, Ascending Series	- - - - - - - - - - -	'Break'
Number of the work periods	0 1 2 3 4 5 6 7 8 9 10	
	←II	
First Unknown, Ascending Series	- - - - - - - - - - -	
		no break
First Unknown, Descending Series	- - - - - - - - - - -	
	←III	'Break'
	0 1 2 3 4 5 6 7 8 9 10	
First Known, Descending Series	- - - - - - - - - - -	
	←IV	

Second Set

	V→	
Second Unknown, Ascending Series	- - - - - - - - - - -	'Break'
	0 1 2 3 4 5 6 7 8 9 10	
	VI→	
Second Known, Ascending Series	- - - - - - - - - - -	
	←VII	no break
Second Known, Descending Series	- - - - - - - - - - -	'Break'
	0 1 2 3 4 5 6 7 8 9 10	
Second Unknown, Descending Series	- - - - - - - - - - -	
	←VIII	

Third Set (Isometric Contractions)

	I→	
First Known, Ascending Series	- - - - - -	
Number of the Work Periods	0 1 2 3 4 5	
		←II
First Unknown, Descending Series	- - - - - -	
	III→	
Second Known, Ascending Series	- - - - - -	
	0 1 2 3 4 5	
		←IV
Second Known, Descending Series	- - - - - -	

Note: The broken lines represent the work periods of a series. The figures designate the duration in seconds of the rests in each work period and at the same time number the periods. The arrows indicate the order in which the work periods were performed.

It will be noticed that in the first set the two known occupy the least, and most, favorable positions with respect to practice effects. The two unknown series occupy a more favorable position than the first known series and a less favorable position than the second known series with respect to practice effects. This sequence permits a fairly equitable distribution of the effects of practice.

In the second set the two unknown and the two known series exchange positions with the two known and the two unknown

series of the first set of experiments. The sequence of series in the first set and the reversal of the sequence (with respect to 'known' or 'unknown') in the second set distribute equally the advantages and disadvantages due to position.

In passing from the last work period of the *ascending* known of the first *set* to the zero work period of the *ascending* unknown of the same set a drop or 'break'; i.e. an abrupt transition from ten rests to no rests occurs. This is equally true of the first unknown and known of the descending series of the same set except that the break occurs in the reverse order. In this instance the transition is abrupt from a condition of no rest in the zero period to the maximum rest in the tenth period; in the former instance the transition or 'break' is from a condition of maximum rest in the tenth period to no rest in the zero period. We not only have to do here with the phenomenon of adaptation but adaptation under different conditions. This phenomenon of 'break' does not prevail between the two unknown ascending and descending (arrows, II & III, p. 6) series where the ascent of the one is followed by the gradual descent of the other. The same is true of the two known ascending and descending series (arrows VI & VII, p. 6) of the second set. Whatever advantages or disadvantages, if any, accrue to either the known or unknown series of the first set because of 'breaks' is fully covered by reversing the order of the series of the second set. We find, then, the first break of the first set between the first ascending known and unknown series paralleled by a break between the ascending unknown and known series of the second set. We find 'no break' between the two unknown series of the first set paralleled by 'no break' between the two known series of the second set. Further, the break between the descending unknown and known series of the first set is paralleled by a similar break in the descending known and unknown series of the second set.

In any ascending or descending series the subject observed a general adaptation or "attunement" of the system to rests as they increased or decreased. This is evident when it is observed (Table 5) that in the concluding work period of one of the ascending series there are 247 subdivisions (each subdivision com-

prises 10 lifts alternating with 10 seconds rest) with a total rest time of 41′ and a total work time of 41′, 1″. For this period the subject is in the machine 1 hr., 22 min., 1 sec. It should be noticed too that the immediately preceding work period covers a total time of 52 min. and 16 sec. From this condition of relative adaptation to long rest periods in an unknown series the subject begins the zero work period of a known series with no rest (Table 6). The brief duration, 2 min., 12 sec., of this work period stands in strong contrast to the immediately preceding work period mentioned above. The long interval of time separating work periods, obviously, obliterated much of the phenomenon of adaptation. That unmistakable traces of such adaptation remain, however, is evident from the subject's tendency to insert rests in the no-rest work period. In several instances such insertion actually occurs as the ergographic records show.

The intensity of the tendency to insert rests in the no-rest work period here under consideration (Table 6, zero period) is determined by the number and amount of rests which the subject made during the immediately preceding series of work periods (Table 5). Reference to this table shows that observer M rests 907 times in the eleven work days and that this amounts to 1 hour 58 min. and 53 seconds. As a consequence there is developed what may be called a *'periodic rest habit.'*

In commenting on the work of the zero period (Table 6) the observer says: "I can resist the tendency to rest here only with the greatest effort. In one or two instances I have actually rested as the records will no doubt show. I get an intense 'rest feel' at the conclusion of each tenth lift. This is interesting in that I seem driven by a sort of organic urgency amounting to inner necessity to insert the rests. How the rests are finally inhibited I am unable to explain."

What we have here is an advanced stage of habituation in which the tenth lift and a rest form fixed associates so that the appearance of the requisite number of lifts conditions the appearance of the rest. With a still more advanced stage of habituation the rests would be expected to follow the lifts more readily and persistently. The insertion of rests in a zero work period men-

tioned by the observer and indicated in the records clearly shows the presence of a conditioned reflex.

The mental complex takes on essentially new features when passing from the eleventh work period of the known series to the zero work period of the unknown series of the first set of experiments; similarly, when passing immediately from one extreme work period of any series, whether ascending or descending, to an opposite extreme of any other series, the conscious content accompanying such periods varies widely from that content common to consecutive work periods. Certain of these conscious features indicate the presence of unfavorable conditions for increased efficiency. Observer remarks: "I experience a peculiar depressing attitude, a distinct feeling of disinclination as I approach the concluding work periods of an ascending series. This feeling is quite the reverse of that characterizing a descending series. All extended work periods whether in ascending or descending series contain elements tending to decrease effort." The influence of such elements are reflected in the efficiencies of any two successive work periods which are separated by wide differences in the number of rest seconds. There is no way of definitely tracing the influence of such elements for the reason that we are dealing here with complex factors and it is undoubtedly true that the elements referred to are merged with such factors as motor attunement, practice effects and the like. It is probable, however, that practice effects exert a positive influence when a work period containing maximal rest seconds is followed by a work period of no rest, while the muscular "set" exerts a negative influence.

The sum for all observers of the absolute (W) values of the above compared work periods preceding the break in adaptation is 675.95 Kg M.; the sum for the periods immediately following the 'break' is 534.34 Kg M. The corresponding unit $\frac{W}{c}$ values are $.8249 \frac{\text{Kg M.}}{\text{Sec.}}$ and $.8781 \frac{\text{Kg M.}}{\text{Sec.}}$. From these data it follows that the periods immediately following the break in adap-

tation are less efficient by 141.61 Kg M. than the corresponding preceding periods. In terms of $\frac{\text{Kg M.}}{\text{Sec.}}$ the efficiency is reversed, that is, after the 'break' the periods immediately succeeding are more efficient by .0532 $\frac{\text{Kg M.}}{\text{Sec.}}$. The absolute values, therefore, stand in inverse relation to the unit values. What degree of differences here noted and to what extent the character of these differences can be ascribed to the phenomenon of adaptation would be difficult to say because of the multiplicity of factors involved. Practice effects and awareness and lack of awareness of results without doubt condition the values here.

The following data taken from observer M are illustrative of the compared periods:

First Break of First Set of Experiments:

Zero period, 1st Asc. Kn. Series	—	6.66 Kg M.	—	.0569	$\frac{\text{Kg M.}}{\text{Sec.}}$
" " 1st " Unkn. "	—	8.65 "	—	.1008	"
		1.99 "		.0439	"

Second Break of First Set of Experiments:

10th per., 1st Desc. Unkn. Series	—	111.37 Kg M.	—	.0918	$\frac{\text{Kg M.}}{\text{Sec.}}$
" " " " Kn. "	—	97.36 "	—	.0764	"
		14.01 "		.0154	"

First Break of Second Set of Experiments:

Zero per., 2nd. Asc. Unkn. Series	—	12.00 Kg M.	—	.0857	$\frac{\text{Kg M.}}{\text{Sec.}}$
" " " " Kn. "	—	11.64 "	—	.0883	"
		.36 "		.0026	"

Second Break of Second Set of Experiments:

10th per., 2nd. Desc. Kn. Series	—	233.23 Kg M.	—	.0923	$\frac{\text{Kg M.}}{\text{Sec.}}$
" " " " Unkn. "	—	132.06 "	—	.0999	"
		101.17 "	—	.0076	"

It has already been noted that the arrangement of the various series in the first and second sets of experiments is intended to distribute equally the advantages and disadvantages to the known and unknown series.

The third set of experiments effectually eliminates all breaks between series whether known or unknown. The muscular adaptation to gradually increasing rest in an ascending series is followed by an adaptation to gradually decreasing rest in a descending series. In this set of experiments as in the first set the unknown series occupy the least, and most, favorable positions. The maximum rest in any subdivision of a series is five seconds while the minimum is zero as in the preceding sets. A fourth set, bearing the same relation to the third set as the second set bears to the first, was made impossible by the withdrawal of the observers. The ergographic load for this third set was six kilograms while for the first and second sets it was four kilograms.

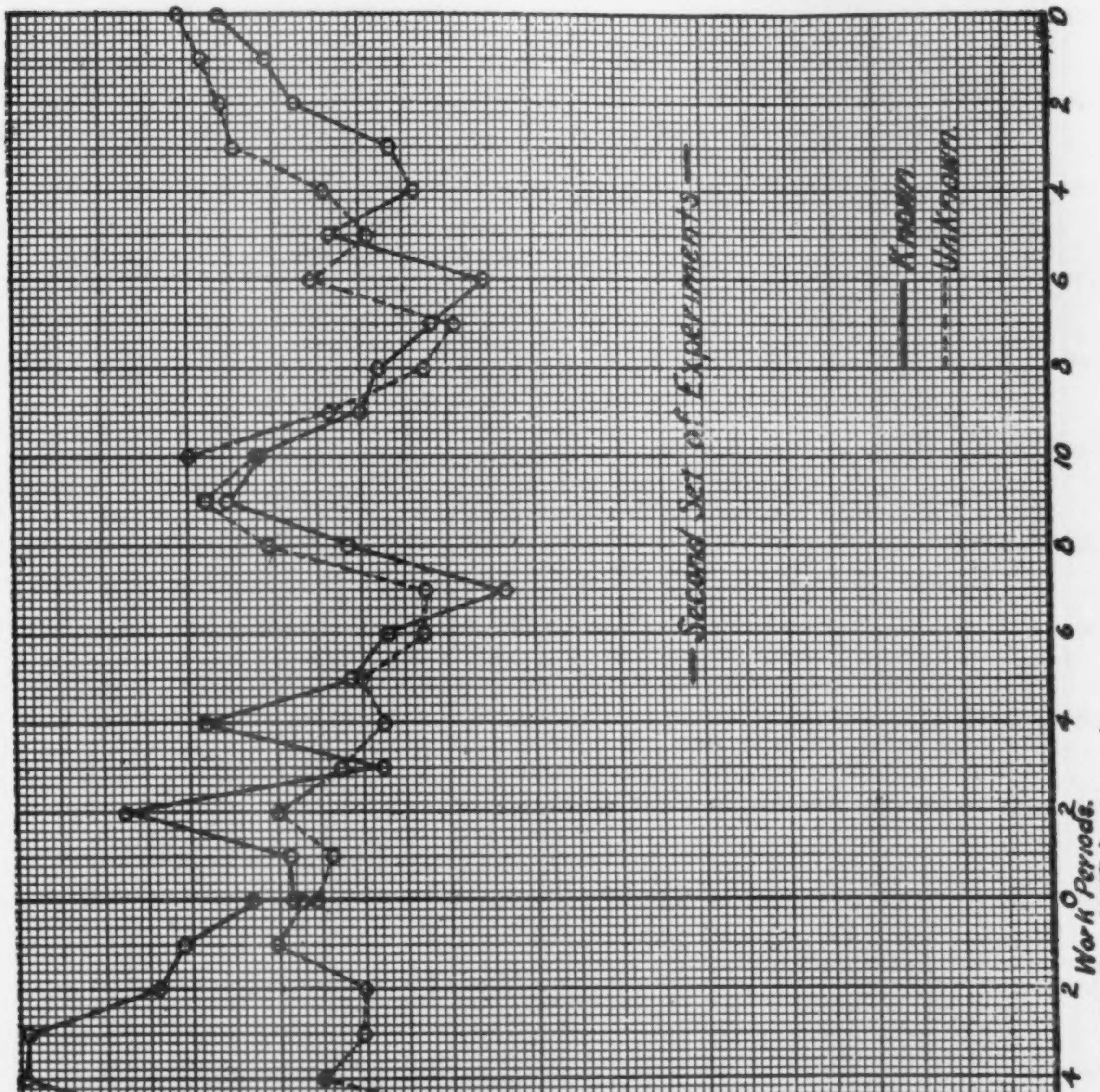
The isometric method (spring) was employed throughout for both loads. The Bergström ergograph is adapted to this method although it could be made to serve the isotanic method.[6]

RESULTS

In the three sets of experiments there are six unknown and six known series which together constitute one hundred twelve work periods. Each known work period has a corresponding unknown period, and each period, whether known or unknown, has an *absolute* and a *unit* efficiency value. For example, in Table I the absolute and unit values of the fifth work period of the ascending known series are 22.84 kilogrammeters and .0954 kilogrammeter seconds (Kg M/Sec.) respectively. The corresponding values in the ascending unknown series are, 22.94 Kg M. and .0703 Kg M/sec. (Table II) In this particular case the absolute values are equivocal while the unit value of the known clearly exceeds that of the unknown. If now the remaining periods are considered in the same manner we get the following variety of relations:

1. In forty-six cases the absolute and unit values of the known periods stand in direct relation to the corresponding values of the unknown periods. In these cases the two kinds of values of the known periods exceed that of the unknown.

[6] The literature setting forth the merits of the two methods is cited by T. A. Storey in the Amer. Journ. of Physiol. Vol. 8, p. 358.



Curve I. (Table I to VIII inclusive).

TABLES I AND II

First Ascending Known. Load 4 Kilograms (Observer M).

B	C min.	C sec.	I	III min.	III sec.	C+III min.	C+III sec.	D	W	$\frac{W}{C}$	$\frac{W}{C+III}$	MWJ	WP
1	1	57	0	0	0	1	57	1.665	6.66	.0569	.0569	.0595	.0595
12	1	53	1	0	11	2	4	2.073	8.29	.0733	.0669	.0805	.0737
11	1	46	2	0	20	2	6	2.330	9.32	.0879	.0740	.0878	.0735
12	1	56	3	0	33	2	29	2.276	9.10	.0785	.0610	.0854	.0338
21	3	37	4	1	24	5	1	4.877	19.51	.0899	.0649	.0828	.0605
24	3	59	5	1	55	5	54	5.710	22.84	.0954	.0646	.0883	.0614
23	3	49	6	2	12	6	1	5.447	21.79	.0949	.0603	.0859	.0549
32	5	16	7	3	37	8	53	6.144	24.57	.0776	.0461	.0789	.0481
32	5	27	8	4	8	9	35	8.482	33.93	.1008	.0589	.0908	.0627
54	8	59	9	7	57	16	56	13.921	55.68	.1003	.0548	.0917	.0497
55	9	17	10	9	0	18	17	13.693	54.77	.0985	.0500	.0917	.0465

First Ascending Unknown. Load 4 Kilograms.

B	C min.	C sec.	I	III min.	III sec.	C+III min.	C+III sec.	D	W	$\frac{W}{C}$	$\frac{W}{C+III}$	MWJ	WP
1	1	20	0	0	0	1	20	2.162	8.65	.1008	.1008	.0705	.0725
11	1	54	1	0	10	2	4	2.642	10.57	.0926	.0851	.0893	.0788
13	2	18	2	0	24	2	42	2.905	11.62	.0843	.0717	.0876	.0739
15	2	25	3	0	42	3	7	3.101	12.40	.0856	.0664	.0747	.0595
21	3	35	4	1	20	4	55	4.382	17.53	.0816	.0593	.0707	.0579
33	5	26	5	2	40	8	6	5.734	22.94	.0703	.0471	.0714	.0479
21	3	35	6	2	0	5	35	4.339	17.36	.0806	.0518	.0708	.0454
40	6	37	7	4	33	11	10	6.746	26.98	.0679	.0402	.0677	.0407
64	10	40	8	8	24	19	4	9.781	39.12	.0612	.0342	.0624	.0350
101	16	52	9	15	0	31	52	19.528	78.11	.0771	.0408	.0658	.0350
90	15	0	10	15	0	30	0	17.584	70.34	.0781	.0407	.0692	.0354

B = Number of subdivisions of work periods.
C = Total time at work.
I = Length of rest period in seconds and designation of the period.[1]
III = Total rest time.
C+III = Total time of work and rest.
D = Distance load travels in meters.
W = Work done in kilogrammeters.
$\frac{W}{C}$ = Unit value per second of work done each period.
$\frac{W}{C + III}$ = Rate of work including the rest time.
MWJ = Average unit value ($\frac{W}{c}$) of all observers.
WP = Average rate of work per second for each period including the rest time.

[1] Attention is called to the fact that the periods, 0, 1, 2, 3, 4 - - - - 10 are the 1st, 2nd, 3rd, 4th, 5th - - - - 11th in the order of performance respectively.

TABLES III AND IV

B	C min.	C sec.	I	III min.	III sec.	C+III min.	C+III sec.	D	W	W/C	W/(C+III)	MWJ	WP
	First Descending Unknown.							Load 4 Kilograms. (Observer M)					
122	20	13	10	20	10	40	23	27.843	111.37	.0918	.0458	.0814	.0383
81	13	30	9	12	0	25	30	16.072	64.29	.0794	.0419	.0803	.0409
89	14	46	8	11	44	26	30	16.297	65.19	.0736	.0410	.0669	.0373
121	20	11	7	14	0	34	11	16.560	66.24	.0663	.0323	.0627	.0351
51	9	36	6	5	36	15	12	8.989	35.96	.0624	.0394	.0608	.0383
55	9	16	5	4	30	13	46	9.160	36.64	.0659	.0445	.0612	.0414
29	4	55	4	1	52	6	47	6.262	25.05	*.0850*	.0616	.0662	.0382
24	4	6	3	1	9	5	15	4.951	19.80	.0804	.0629	.0723	.0564
19	3	16	2	0	36	3	52	3.925	15.70	.0801	.0681	.0759	.0648
19	3	12	1	0	19	3	30	4.341	17.36	.0904	.0826	.0768	.0704
1	2	2	0	0	0	2	2	2.660	10.64	.0873	.0873	.0713	.0700
	First Descending Known.							Load 4 Kilograms.					
128	21	14	10	21	10	42	24	24.340	97.36	.0764	.0382	.0804	.0404
88	14	34	9	13	3	27	37	16.717	66.87	.0764	.0404	.0793	.0418
126	20	55	8	16	40	37	35	10.781	79.12	.0630	.0351	.0675	.0377
98	16	15	7	11	19	27	34	18.389	73.56	.0755	.0445	.0761	.0453
59	9	43	6	5	48	15	31	12.200	48.80	.0837	.0524	.0824	.0518
93	15	22	5	7	40	23	2	24.500	98.00	.1006	.0709	.0735	.0500
67	11	6	4	4	24	15	30	14.964	79.86	*.1195*	.0859	.0793	.0572
24	4	0	3	1	9	5	9	7.108	28.43	.1190	.0923	.0963	.0748
20	3	13	2	0	38	3	51	5.017	20.07	.1040	.0872	.0951	.0803
16	2	33	1	0	15	2	48	3.863	15.45	.1010	.0920	.0832	.0763
1	2	0	0	0	0	2	0	2.795	11.18	.0930	.0930	.0783	.0782

2. In twenty-three cases the absolute and unit values of the unknown periods stand in direct relation to the corresponding values of the known periods. In these cases the two kinds of values of the unknown periods exceed that of the known.

3. In thirty-one cases the unit values of the known work periods stand in inverse relation to the corresponding absolute values of the unknown periods. In these cases the unit values of the known work periods and the absolute values of the unknown work periods are more efficient than their corresponding values. For example, consider the third work period (Table I). Here the absolute (W) value is 9.32 Kg M. and the unit $\left(\frac{W}{c}\right)$ value is .0879 $\frac{\text{Kg M.}}{\text{Sec.}}$ for the known series of work periods. The corresponding values (Table II) for the unknown series are 11.62 Kg M. and .0843 $\frac{\text{Kg M.}}{\text{Sec.}}$. The unit value (.0879 $\frac{\text{Kg M.}}{\text{Sec.}}$)

of the known and the absolute value (11.62 Kg M.) of the unknown series are more efficient than their respective corresponding values, ($.0843 \frac{\text{Kg M.}}{\text{Sec.}}$ and 9.32 Kg M.)

4. In twenty-one cases the unit values of the known work periods stand in inverse relation to the corresponding absolute values of the unknown periods. In these cases, however, the unit values of the known work periods and the absolute values of the unknown work periods are less efficient than their corresponding values.

The following summary of Tables III and IV is illustrative of the treatment of all the tables as summarized above:

First Descending Known and First Descending Unknown Series.

	Absolute values of known work periods indicated with symbols, greater (>) or less (<) than the corresponding unknown values.	*Unit* values of known work periods indicated with symbols, greater (>) or less (<) than the corresponding unknown values.
0 work period	<	>
1 " "	<	>
2 " "	>	>
3 " "	>	>
4 " "	>	>
5 " "	>	>
6 " "	>	>
7 " "	>	>
8 " "	>	<
9 " "	>	<
10 " "	<	<

Periods 0 and 1 are illustrative of the thirty-one cases above. Periods 2, 3, 4, 5, 6, and 7 are illustrative of the forty-six cases above. Periods 8 and 9 are illustrative of the twenty-one cases above. Period 10 is illustrative of the twenty-three cases above.

Of the total number of cases (121) 38 per cent show a higher efficiency value, absolute and unit, for the known as compared to 19 per cent of the unknown work periods. In 26 per cent of the cases the unit values of the known and the absolute values of the unknown show a higher efficiency, while the unit values of the unknown and the absolute values of the known show a high efficiency in 17 per cent of the cases. Combining the above percentages we find 64 per cent of the unit values and 55 per cent of the absolute values of the known work periods show a higher

efficiency than the corresponding values for the unknown periods.

If the conditions of the experiment secure an equitable distribution of the complex factors involved in each work period such as adaptation, fatigue, ergographic defects and the like, then we may conclude that the increased efficiency of the known periods over that of the unknown is conditioned by the conscious factor of awareness of results. This means that the organism functions more effectively when the ergographic tracings are immediately present stimuli.

The influence of this factor may be found by comparing the absolute and unit efficiency values for the known and unknown periods as given in Table I to VIII and XIII to XIX inclusive. A summary is given in Table XXII.

In three work periods the average unit values (WP) of the unknown periods exceed that of the known. These are the 0, 2, and 3 periods and are indicated by the less sign (<) in Table XX. In one work period only do the average unit values ($\frac{W}{c}$ for M W J) of the unknown exceed in efficiency those of the known periods. This is the zero period and is indicated by the less sign (<) in Table XX.

The relation of the grand averages of the various efficiency values for all the work periods of the known and unknown series is found in Table XXII.

As Table XX shows the average unit values of the various series so Table XXI shows the average absolute values for the same series. Reference to Table XXI shows that in two work periods only (0 and 1) do the average absolute values of the unknown exceed that of the known periods. An average of all the work periods of all the observers shows the known series to excel in absolute efficiency that of the unknown by .84 Kg M. (Table XXII). A similar average of the unit values shows the known series to excel that of the unknown by .0053 $\frac{\text{Kg M.}}{\text{Sec.}}$ (Table XXII).

TABLES V AND VI.

Second Ascending Unknown. Load 4 Kilograms. (Observer M)

B	C min.	C sec.	I	III min.	III sec.	C+III min.	C+III sec.	D	W	W/C	W/C+III	MWJ	WP
1	2	20	0	0	0	2	20	3.000	12.00	.0857	.0857	.0814	.0817
20	3	15	1	0	18	3	33	4.090	16.36	.0838	.0767	.0769	.0704
16	2	44	2	0	30	3	14	3.468	13.87	.0900	.0714	.0873	.0731
32	5	16	3	1	33	6	49	6.509	26.04	.0825	.0637	.0847	.0641
31	5	6	4	2	0	7	6	5.925	23.70	.0774	.0556	.0657	.0473
70	11	32	5	9	55	21	27	13.834	55.34	.0800	.0430	.0663	.0414
82	13	33	6	8	6	21	39	14.812	59.24	.0729	.0456	.0710	.0446
83	13	42	7	9	34	23	16	14.880	59.52	.0726	.0426	.0696	.0410
160	26	30	8	21	12	47	42	35.097	140.39	.0907	.0496	.0726	.0404
166	27	31	9	24	45	52	16	40.385	161.54	.0979	.0515	.0864	.0459
247	41	1	10	41	0	82	1	56.586	226.34	.0920	.0461	.0761	.0448

Second Ascending Known. Load 4 Kilograms.

B	C min.	C sec.	I	III min.	III sec.	C+III min.	C+III sec.	D	W	W/C	W/C+III	MWJ	WP
1	2	12	0	0	0	2	12	2.910	11.64	.0883	.0883	.0820	.0816
17	2	48	1	0	16	3	4	3.721	14.88	.0886	.0809	.0875	.0800
19	3	10	2	0	36	3	46	5.108	20.43	.1075	.0906	.0883	.0747
28	4	36	3	0	21	5	57	5.381	21.52	.0778	.0606	.0750	.0586
31	5	4	4	2	0	7	4	7.446	29.78	.0981	.0701	.0726	.0532
42	6	55	5	3	25	10	20	8.462	33.85	.0814	.0546	.0663	.0446
85	14	3	6	8	24	22	27	16.235	64.94	.0770	.0482	.0625	.0404
147	24	21	7	17	2	41	23	23.173	92.69	.0634	.0373	.0679	.0383
189	31	5	8	25	4	56	9	38.363	153.45	.0815	.0455	.0844	.0474
209	34	50	9	31	12	66	2	49.757	199.03	.0953	.0504	.0864	.0409
262	43	33	10	43	30	87	3	61.160	244.64	.0917	.0470	.0785	.0397

TABLES VII AND VIII.

Second Descending Known. Load 4 Kilograms. (Observer M)

B	C min.	C sec.	I	III min.	III sec.	C+III min.	C+III sec.	D	W	W/C	W/C+III	MWJ	WP[1]
263	43	50	10	43	40	*87*	*30*	58.308	233.23	*.0923*	.0443	.0788	.0585
202	33	40	9	30	9	*63*	*49*	40.389	161.56	*.0800*	.0422	.0745	.0393
142	23	31	8	18	48	42	19	27.474	109.90	.0778	.0399	.0688	.0355
94	15	42	7	11	21	27	3	16.887	67.55	.0718	.0417	.0785	.0460
106	18	37	6	10	30	28	7	17.365	69.46	.0656	.0411	.0687	.0431
64	10	31	5	5	15	15	46	13.147	52.59	.0833	.0556	.0783	.0524
48	7	54	4	8	3	15	57	8.730	34.92	.0737	.0364	.0664	.0392
39	6	13	3	1	51	8	4	6.861	27.44	.0763	.0569	.0648	.0493
17	2	42	2	0	32	3	14	3.537	14.15	.0872	.0729	.0786	.0443
15	2	22	1	0	14	2	36	3.220	12.88	.0907	.0827	.0886	.0809
1	1	55	0	0	0	0	55	2.765	11.00	.0960	.0960	.0898	.0898

Second Descending Unknown. Load 4 Kilograms.

B	C min.	C sec.	I	III min.	III sec.	C+III min.	C+III sec.	D	W	W/C	W/C+III	MWJ	WP
133	22	1	10	22	0	44	1	33.015	132.06	.0999	.0498	.0896	.0449
160	26	31	9	23	51	50	22	33.347	133.39	.0835	.0322	.0768	.0305
134	22	12	8	17	44	39	56	24.145	96.58	.0725	.0404	.0648	.0361
156	25	52	7	18	5	43	57	26.778	107.11	.0689	.0407	.0656	.0387
118	19	40	6	11	42	31	22	25.204	100.81	.0854	.0535	.0799	.0502
73	12	3	5	6	0	18	3	14.437	57.75	.0789	.0533	.0672	.0456
63	10	27	4	4	8	14	35	13.157	52.63	.0840	.0602	.0710	.0493
30	4	51	3	1	27	6	18	6.855	21.42	.0943	.0726	.0730	.0564
22	3	34	2	0	42	4	16	5.134	20.54	.0958	.0802	.0879	.0738
16	2	38	1	0	15	2	53	3.870	15.48	.0980	.0895	.0842	.0767
1	1	50	0	0	0	1	50	2.766	11.06	.1005	.1005	.0957	.0957

[1] WP does not include the data of Observer J for the second descending 'known' and 'unknown' series of work periods.

Table IX.

First Ascending Known Series. Load 6 Kilograms. (Observer M.)

B	C		I	III		C+III		C	W	W/C
	Min.	Sec.		Min.	Sec.	Min.	Sec.			
1	1	5	0	0	0	1	5	1.513	7.88	.1029
9	1	33	1	0	8	1	41	1.700	10.20	.1098
10	1	35	2	0	18	1	53	2.193	13.16	.1382
10	1	40	3	0	27	2	7	2.380	14.28	.1428
12	1	53	4	0	44	2	37	2.488	14.93	.1320
11	1	54	5	0	50	2	44	2.407	14.44	.1268

Table X.

First Descending Unknown Series. Load 6 Kilograms.

13	2	2	5	1	0	3	2	2.760	16.56	.1360
10	1	40	4	0	36	2	16	2.372	14.23	.1423
10	1	34	3	0	27	2	1	1.880	11.28	.1198
9	1	25	2	0	16	1	41	2.003	12.03	.1420
7	1	4	1	0	6	1	10	1.517	8.10	.1420
1	1	1	0	0	0	1	1	1.410	8.46	.1386

Table XI.

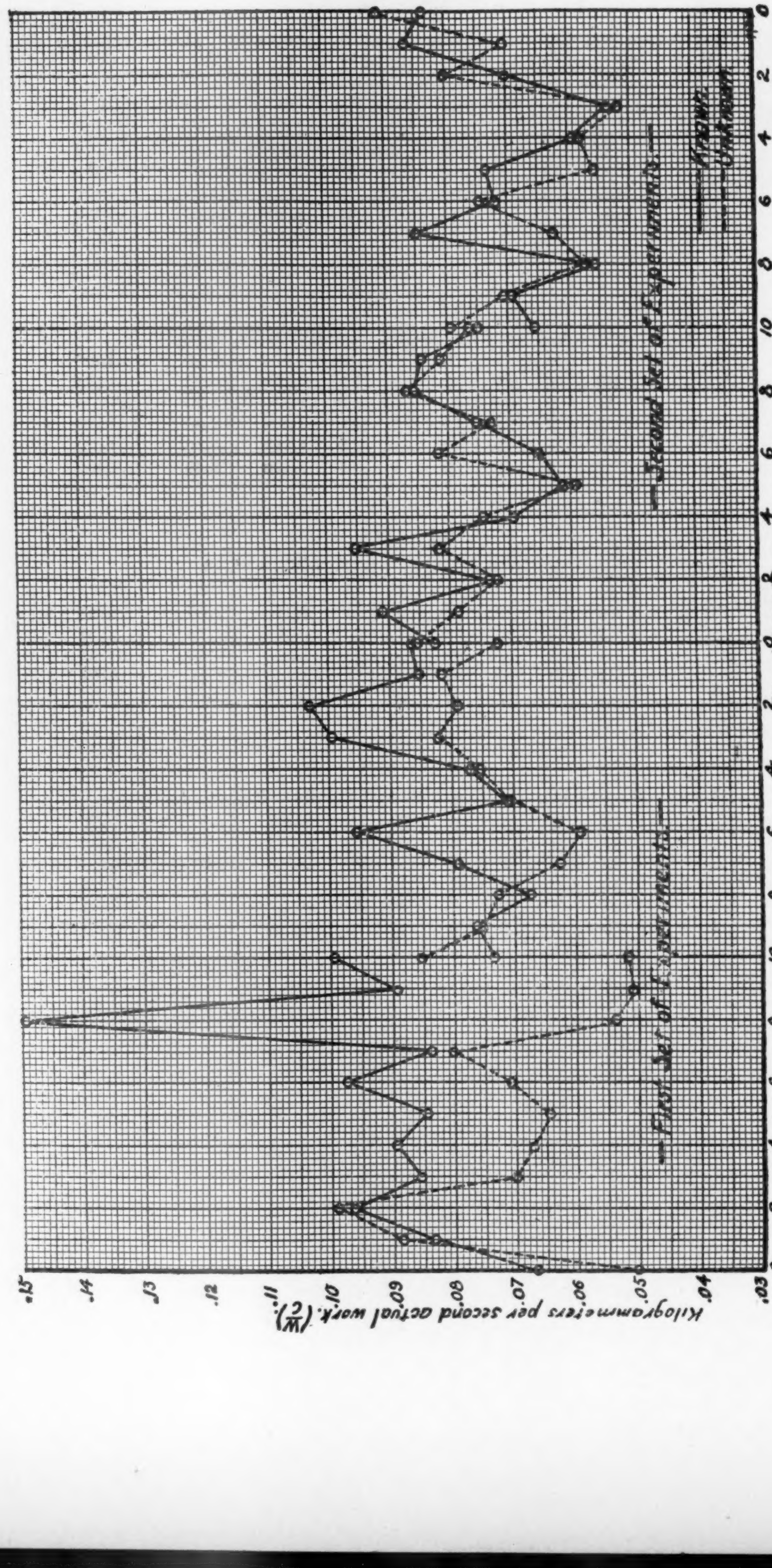
Second Ascending Known Series. Load 6 Kilograms.

1	0	49	0	0	0	0	49	1.474	8.84	.1822
9	1	24	1	0	8	1	32	2.026	12.16	.1447
9	1	23	2	0	16	1	39	1.955	11.73	.1414
13	2	2	3	0	36	2	38	1.765	10.59	.0868
15	2	22	4	0	56	3	18	3.325	19.95	.1404
13	2	3	5	1	0	3	3	2.116	12.70	.1003

Table XII.

Second Descending Known Series. Load 6 Kilograms.

14	2	14	5	1	5	3	19	3.200	19.20	.1433
14	2	11	4	0	52	3	3	3.025	18.15	.1384
12	1	53	3	0	33	2	26	2.712	16.27	.1442
8	1	20	2	0	14	1	34	2.136	12.82	.1602
9	1	22	1	0	8	1	30	2.127	12.76	.1556
1	1	6	0	0	0	1	0	1.735	10.41	.1578



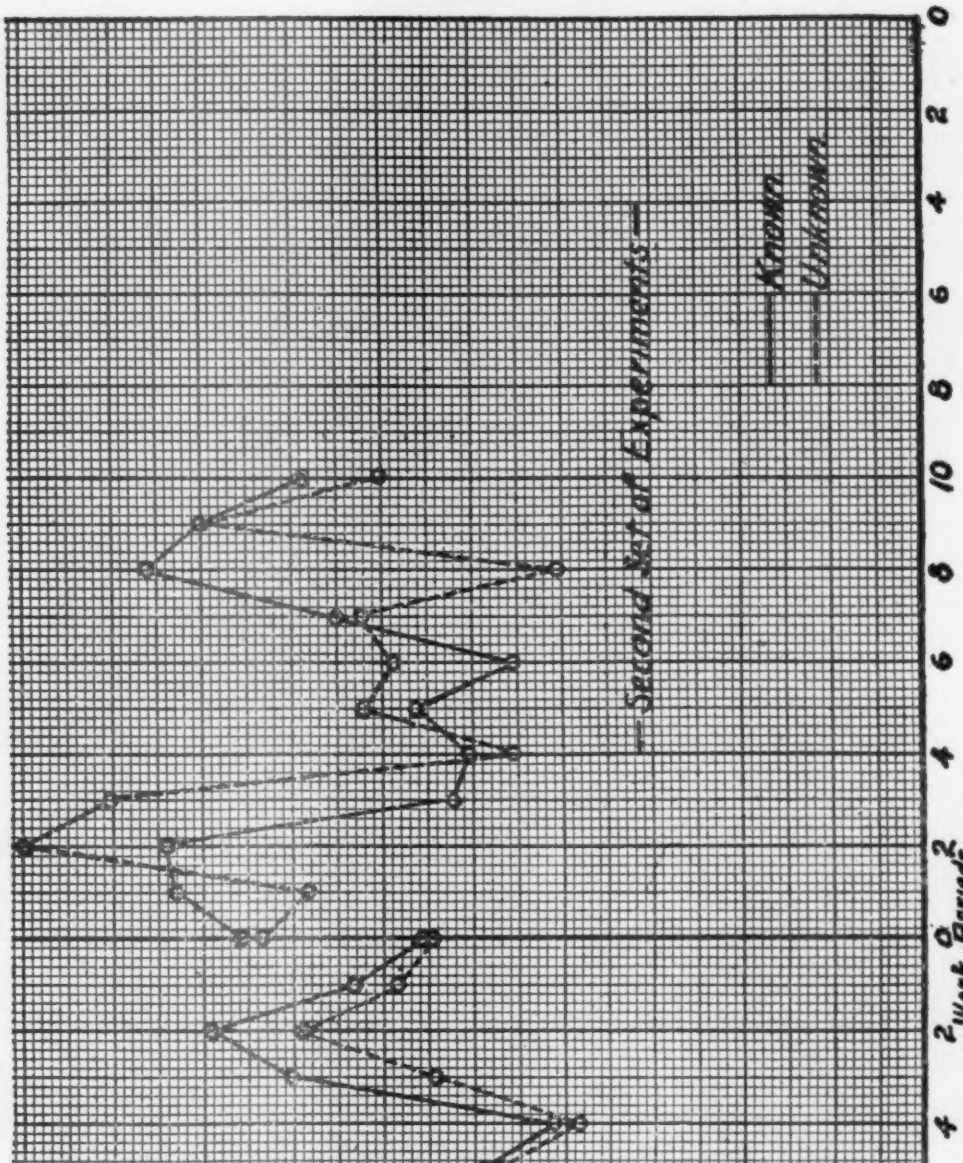
Curve 2. (Tables XIII, XV, XVII, and XIX).

TABLE XIII.

B	C		I	III		C+III		D	W	W/C	W/(C+III)
	Min.	Sec.		Min.	Sec.	Min.	Sec.				
First Ascending Known.						Load 4 Kilograms.			(Observer W.)		
1	1	32	0	0	0	1	32	1.53	6.12	.0665	.0665
9	1	35	1	0	8	1	43	1.98	7.92	.0833	.0768
11	1	40	2	0	20	2	0	2.41	9.64	.0964	.0800
10	1	35	3	0	27	2	2	2.03	8.12	.0854	.0665
15	2	34	4	0	56	3	30	3.45	13.80	.0896	.0657
14	2	28	5	1	5	3	33	3.12	12.48	.0843	.0585
21	3	37	6	2	–	5	37	5.29	21.16	.0975	.0627
29	4	52	7	3	16	7	68	6.21	24.84	.0838	.0501
36	4	1	8	4	40	8	41	9.01	36.04	*.1495*	.0691
30	5	9	9	4	21	9	30	6.90	27.60	.0893	.0484
43	7	15	10	7	0	14	15	10.82	43.28	.0994	.0505
First Ascending Unknown.						Load 4 Kilograms.					
1	1	53	0	–	–	1	53	1.42	5.68	.0502	.0502
10	1	40	1	–	9	1	49	2.21	8.84	.0884	.0811–
8	1	22	2	–	14	1	36	2.03	8.12	.0990	.0845–
15	2	38	3	–	42	3	20	2.76	11.06	.0700	.0553–
12	2	8	4	–	44	2	52	2.15	8.60	.0671	.0500–
18	3	4	5	1	35	4	39	2.97	11.88	.0645	.0425–
23	3	58	6	2	12	6	10	4.21	16.84	.0707	.0455–
39	6	32	7	4	26	10	58	2.83	31.36	.0800	.0476
40	6	45	8	5	12	11	57	5.42	21.68	*.0535*	.0302
54	9	3	9	7	51	17	–	6.92	27.68	.0509	.0272
63	10	39	10	10	20	20	50	8.24	32.96	.0515	.0263

TABLE XIV.

B	C		I	III		C+III		D	W	W/C	W/(C+III)
	Min.	Sec.		Min.	Sec.	Min.	Sec.				
First Ascending Known.						Load 4 Kilograms.			(Observer J.)		
1	1	48	0	0	0	1	48	1.49	5.96	.0552	.0551
12	1	54	1	0	11	2	5	2.42	9.68	.0848	.0774
10	1	41	2	0	18	1	59	1.98	7.92	.0792	.0665
13	2	18	3	0	36	2	54	3.18	12.72	.0922	.0731
18	3	9	4	1	8	4	17	3.26	13.04	.0691	.0509
22	3	47	5	1	45	5	32	5.08	20.32	.0851	.0612
20	3	25	6	1	55	5	20	3.35	13.40	.0654	.0418
29	4	58	7	3	16	8	6	5.61	22.44	.0753	.0461
28	4	43	8	3	36	8	16	6.24	24.96	.0882	.0503
44	7	27	9	6	27	13	47	9.54	38.17	.0854	.0461
54	9	9	10	8	50	17	59	10.58	42.32	.0771	.0390
First Ascending Unknown.						Load 4 Kilograms.					
1	1	30	0	0	0	1	30	1.50	6.00	.0606	.0666
11	1	52	1	0	10	2	2	2.15	8.60	.0769	.0704
15	2	36	2	0	28	3	4	3.02	12.09	.0795	.0657
21	3	31	3	1	0	4	31	3.61	14.45	.0685	.0570
15	2	32	4		56	3	28	3.36	13.44	.0634	.0646
28	4	49	5	2	15	7	4	5.73	22.94	.0794	.0541
47	7	56	6	4	36	12	26	7.28	29.13	.0612	.0390
42	7	4	7	4	47	11	51	6.13	24.54	.0553	.0345
54	9	7	8	7	4	16	11	9.90	39.60	.0724	.0407
68	11	28	9	10	3	21	31	11.97	47.88	.0696	.0370
70	11	42	10	11	30	23	12	13.68	54.75	.0780	.0393



Curve 3. (Tables XII, XVI, XVIII).

TABLE XV.

B	C		I	III		C+III		D	W	W / C	W / C+III
	Min.	Sec.		Min.	Sec.	Min.	Sec.				
First Descending Known. Load 4 Kilograms (Observer W).											
93	15	36	10	15	20	30	56	17.17	68.70	.0734	.0370
79	13	15	9	11	42	24	57	15.14	60.58	.0762	.0405
90	15	9	8	11	52	27	1	15.29	61.17	.0673	.0377
65	10	56	7	7	28	18	24	13.20	52.78	.0791	.0478
60	10	8	6	5	54	16	2	14.53	58.12	.0956	.0605
75	12	33	5	6	10	18	43	13.40	53.60	.0710	.0477
50	8	28	4	3	16	11	44	9.80	39.22	.0772	.0557
38	6	25	3	1	51	8	16	9.58	38.31	.0995	.0772
15	2	37	2	0	28	3	5	4.00	16.01	.1030	.0865
8	1	23	1	0	7	1	30	1.77	7.06	.0851	.0784
1	1	20	0	0	0	1	20	1.73	6.90	.0863	.0862
First Descending Unknown. Load 4 Kilograms.											
85	14	10	10	14	0	28	10	18.08	72.34	.0851	.0360
50	8	27	9	7	21	15	48	9.51	38.03	.0750	.0401
53	8	56	8	6	56	15	52	9.70	38.81	.0724	.0407
86	14	29	7	9	55	24	24	13.58	54.31	.0625	.0371
70	11	42	6	6	54	18	36	10.39	41.56	.0592	.0372
45	7	35	5	3	40	11	15	7.99	31.94	.0702	.0473
15	2	36	4	0	56	3	32	2.94	11.75	.0753	.0554
22	3	41	3	1	3	4	44	4.54	18.14	.0821	.0639
10	1	46	2	0	18	2	4	2.09	8.35	.0788	.0673
12	2	4	1	0	11	2	15	2.53	10.11	.0815	.0748
1		58	0	0	0	0	58	1.05	4.18	.0721	.0720

TABLE XVI.

B	C		I	III		C+III		D	W	W / C	W / C+III
	Min.	Sec.		Min.	Sec.	Min.	Sec.				
First Descending Known. Load 4 Kilograms (Observer J).											
110	18	29	10	18	10	36	39	25.37	101.47	.0915	.0461
83	13	55	9	12	18	26	13	18.29	73.14	.0852	.0465
95	15	56	8	12	32	28	28	17.23	68.93	.0721	.0403
62	10	23	7	7	7	17	30	11.46	45.85	.0736	.0438
70	11	48	6	6	54	18	42	12.00	48.00	.0678	.0427
32	5	22	5	2	35	7	57	3.94	15.75	.0489	.0314
25	4	17	4	1	36	5	53	2.65	10.61	.0413	.0300
24	4	9	3	1	9	5	18	4.37	17.50	.0703	.0550
10	1	42	2		18	2	00	2.02	8.08	.0792	.0673
6	1	3	1		5	1	8	1.00	3.98	.0632	.0585
1	1	20	0			1	20	1.11	4.44	.0555	.0555
First Descending Unknown. Load 4 Kilograms.											
98	16	28	10	16	20	32	48	16.60	66.40	.0674	.0332
115	19	12	9	17	6	36	18	24.91	99.65	.0865	.0411
100	16	41	8	13	20	30	1	13.66	54.65	.0546	.0303
43	7	17	7	4	44	10	1	6.48	25.91	.0593	.0359
55	9	16	6	5	24	14	40	8.44	33.75	.0607	.0383
22	3	43	5	1	45	5	28	2.66	10.66	.0476	.0324
18	3	4	4	1	8	4	12	1.74	6.97	.0384	.0276
21	3	37	3	1	00	4	37	2.95	11.78	.0543	.0425
8	1	25	2		14	1	39	1.47	5.87	.0690	.0592
12	2	8	1		11	2	19	1.87	7.48	.0584	.0538
1	1	52	0			1	52	1.53	6.10	.0545	0.508

Table XVII

B	C		I	III		C+III		D	W	W/C	W/(C+III)
	Min.	Sec.		Min.	Sec.	Min.	Sec.				
Second Ascending Known. Load 4 Kilograms. (Observer W).											
1	1	58	0	0	0	1	58	2.42	9.71	.0823	.0822
18	3	3	1	0	17	3	20	4.16	16.65	.0910	.0832
12	2	7	2	0	22	2	29	2.33	9.33	.0735	.0632
25	4	15	3	1	12	5	27	6.07	24.28	.0952	.0742
24	4	4	4	1	32	5	36	4.23	16.93	.0694	.0509
39	6	38	5	3	10	9	48	6.99	24.40	.0613	.0415
75	12	31	6	7	24	19	55	12.22	48.89	*.0651*	.0409
54	9	5	7	6	11	15	16	10.20	40.78	.0752	.0445
90	15	4	8	11	52	26	56	19.60	78.38	.0856	.0485
120	20	7	9	17	51	37	58	25.42	101.67	.0841	.0446
193	32	13	10	32	00	64	13	36.19	144.78	.0749	.0375
Second Ascending Unknown. Load 4 Kilograms.											
1	2	5	0	0	0	2	5	2.64	10.65	.0852	.0852
20	3	23	1	0	19	3	42	3.98	15.94	.0785	.0718
10	1	48	2	0	18	2	6	1.94	7.78	.0720	.0633
18	3	20	3	0	51	4	11	3.71	14.83	.0815	.0581
38	6	25	4	2	28	8	53	7.13	28.53	.0741	.0535
63	10	37	5	5	10	15	47	9.06	36.25	.0569	.0380
59	9	51	6	5	48	15	39	12.06	48.23	*.0816*	.0513
85	14	17	7	9	48	24	5	15.83	63.33	.0739	.0437
81	13	31	8	10	40	24	11	17.60	70.39	.0868	.0492
160	26	49	9	23	50	50	39	32.66	130.65	.0812	.0429
174	29	4	10	28	50	57	54	33.31	133.24	.0764	.0383

Table XVIII

B	C		I	III		C+III		D	W	W/C	W/(C+III)
	Min.	Sec.		Min.	Sec.	Min.	Sec.				
Second Ascending Known. Load 4 Kilograms (Observer J).											
1	1	42	0			1	42	1.92	7.69	.0754	.0753
15	2	35	1		14	2	49	3.22	12.86	.0830	.0760
25	4	16	2		48	5	4	5.38	21.50	.0840	.0703
18	3	7	3		51	3	58	2.44	9.74	*.0521*	.0409
65	10	59	4	3	16	14	15	8.27	33.08	.0502	.0385
30	5	1	5	2	25	7	26	4.22	16.89	.0563	.0378
69	11	37	6	4	48	16	25	7.89	31.57	.0453	.0320
110	18	23	7	12	33	30	56	17.92	71.69	.0650	.0332
85	14	18	8	11	12	25	30	18.47	73.87	*.0861*	.0482
160	26	41	9	23	51	50	32	21.17	84.67	.0798	.0278
132	22	3	10	21	50	43	53	22.76	91.02	.0688	.0345
Second Ascending Unknown. Load 4 Kilograms (Observer W).											
1	1	39	0			1	39	1.81	7.27	.0734	.0734
10	1	46	1		9	1	55	1.81	7.24	.0683	.0629
11	1	52	2		20	2	12	2.80	11.19	.0999	.0847
24	4	9	3	1	9	5	18	5.61	22.46	*.0902*	.0706
32	5	28	4	2	4	7	32	3.74	74.96	.0456	.0330
88	14	42	5	6	25	21	7	13.69	54.77	.0621	.0432
52	8	44	6	5	6	13	50	7.67	30.71	.0586	.0369
90	15	6	7	10	32	25	38	14.13	56.53	.0624	.0367
123	20	33	8	16	16	36	49	12.39	49.57	*.0402*	.0224
108	17	29	9	16	3	33	32	21.81	87.23	.0801	.0433
144	24	5	10	23	50	47	55	21.67	86.70	.0600	.0302

TABLE XIX

B	C		I	III		C+III		D	W	W/C	W/(C+III)
	Min.	Sec.		Min.	Sec.	Min.	Sec.				
Second Descending Known. Load 4 Kilograms (Observer W).											
220	36	41	10	36	30	73	11	35.99	143.95	.0654	.0327
175	29	15	9	26	6	55	21	30.32	121.27	.0691	.0365
176	29	26	8	23	20	52	46	24.64	98.54	.0558	.0311
82	13	42	7	9	27	23	9	17.51	70.03	.0852	.0504
91	15	15	6	9	00	24	15	16.45	65.79	.0719	.0452
55	9	13	5	4	30	13	43	10.13	40.53	.0733	.0492
31	5	19	4	2	00	7	19	4.72	18.88	.0592	.0430
23	3	52	3	1	6	4	58	3.10	12.39	.0534	.0418
8	1	24	2	0	14	1	38	1.47	5.89	.0701	.0601
15	2	31	1	0	14	2	45	3.27	13.08	.0866	.0792
1	1	51	0	0	0	1	51	2.32	9.29	.0837	.0836
Second Descending Unknown. Load 4 Kilograms.											
108	18	8	10	17	50	35	58	21.59	86.38	.0793	.0400
109	18	13	9	16	12	34	25	19.18	76.73	.0702	.0289
93	15	37	8	12	16	27	53	13.35	53.40	.0571	.0319
101	16	56	7	11	40	28	36	15.82	63.30	.0623	.0368
89	14	59	6	8	48	23	47	16.74	66.98	.0745	.0469
62	10	21	5	5	5	15	26	8.61	34.47	.0555	.0379
48	8	9	4	3	8	12	17	7.10	28.41	.0581	.0385
21	3	32	3	1	00	4	32	2.74	10.96	.0517	.0402
18	3	5	2	0	34	3	39	3.70	14.80	.0800	.0675
9	1	34	1	0	8	1	42	1.65	6.62	.0704	.0640
1	1	42	0	0	0	1	42	2.32	9.28	.0910	.0909

Of the two values the absolute is less significant, for it is highly improbable that the time rate for the work periods of the known corresponds to that of the unknown. There is no technique, controlling the various incentives to effort, operative for any series. Moreover, there is no absolute assurance that the instruction to make each ergographic lift represent maximal effort actually prevailed. A slower time rate of work may offer opportunity for partial recovery from fatigue and this would be equivalent to an increased period of rest. The absolute values are important here, therefore, in so far as they support the unit values.

A further comparison of the values of the known with the unknown series yields the following results:

1. The final average of the absolute efficiency values of all the known series of the first and second sets of experiments exceeds that of the unknown by .2 percent.

2. The final average of the unit efficiency values of all the known series, excepting the third set of experiments, excels that

of the unknown by 7 percent. In the known work periods the observer worked at a higher rate of speed.

In comparing the data of the third set of experiments of observer M (Table XXII) with the first and second sets we find the following:

(a) The average absolute efficiency value of all the known series exceeds that of the unknown by 10 percent.

(b) The average absolute efficiency value of the known series of the first and second sets of experiments exceeds that of the corresponding unknown by 10 per cent.

(c) The average absolute efficiency value of the known series of the third set of experiments exceeds that of the corresponding unknown by 10 per cent. (The ergograph load in this set is 6 kilograms.)

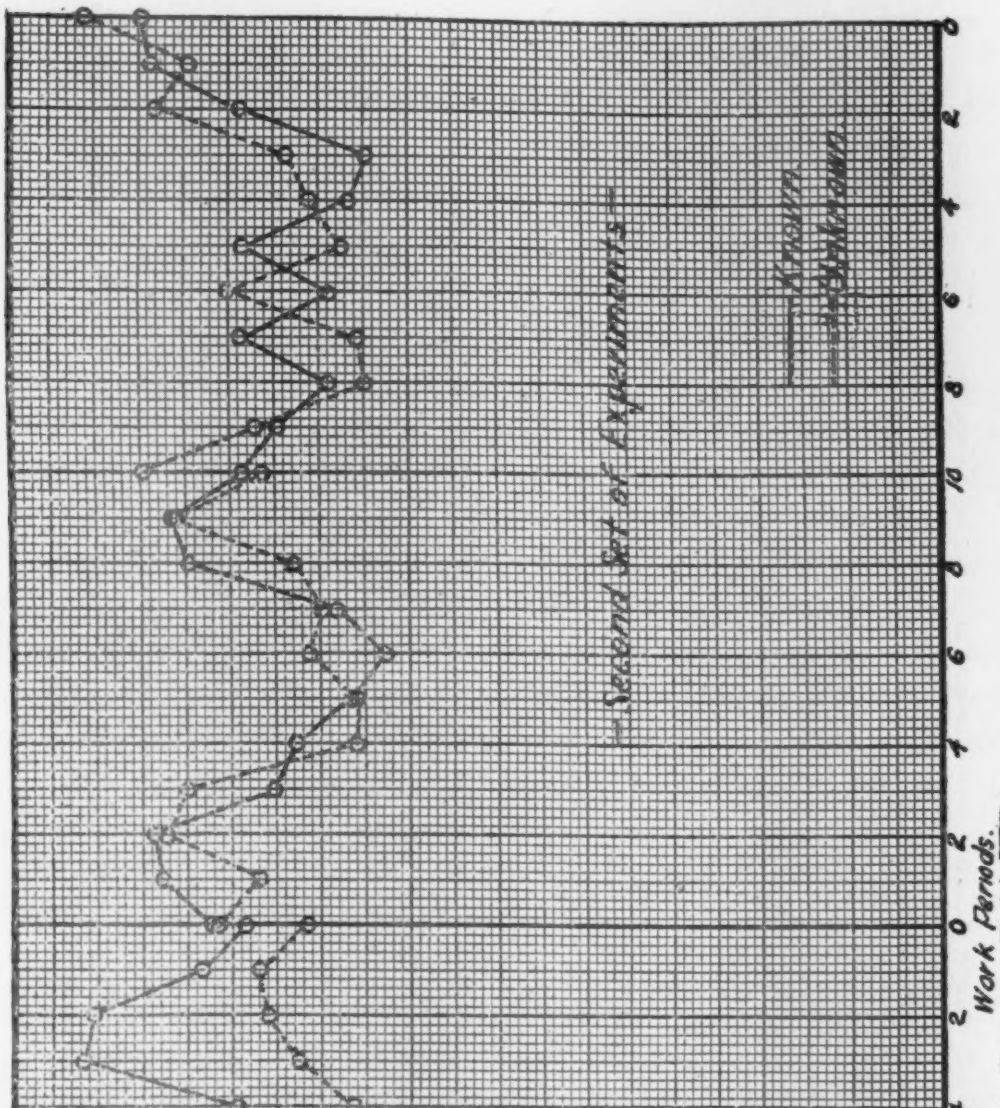
(d) The average unit value of the known series of all sets of experiments shows a higher rate of work by 18 per cent over the corresponding value of the unknown series.

(e) The average unit value of the known series of the first and second sets of experiments shows a higher rate of work (speed) by 5 per cent over its corresponding value of the unknown series.

(f) The average unit value of the known series of the third set of experiments shows a higher rate of work by 35 per cent over the corresponding value of the unknown series.

A comparison of "a" and "b" indicates that the average absolute efficiency value is independent of the ergographic load. The known series is 10 per cent more efficient whether the load is four or six kilograms.

Reference to "e" and "f" shows that the average rate of work is dependent upon the load. Here we find that the average unit value of the known series exceeds that of the unknown by 5 per cent when the ergographic load is 4 kilograms, while the unit value under similar conditions for the known series exceeds by 35 per cent the unknown when the load is increased by 2 kilograms. Within the limits here investigated the rate of work increases directly as the load increases. An increase by one-half of



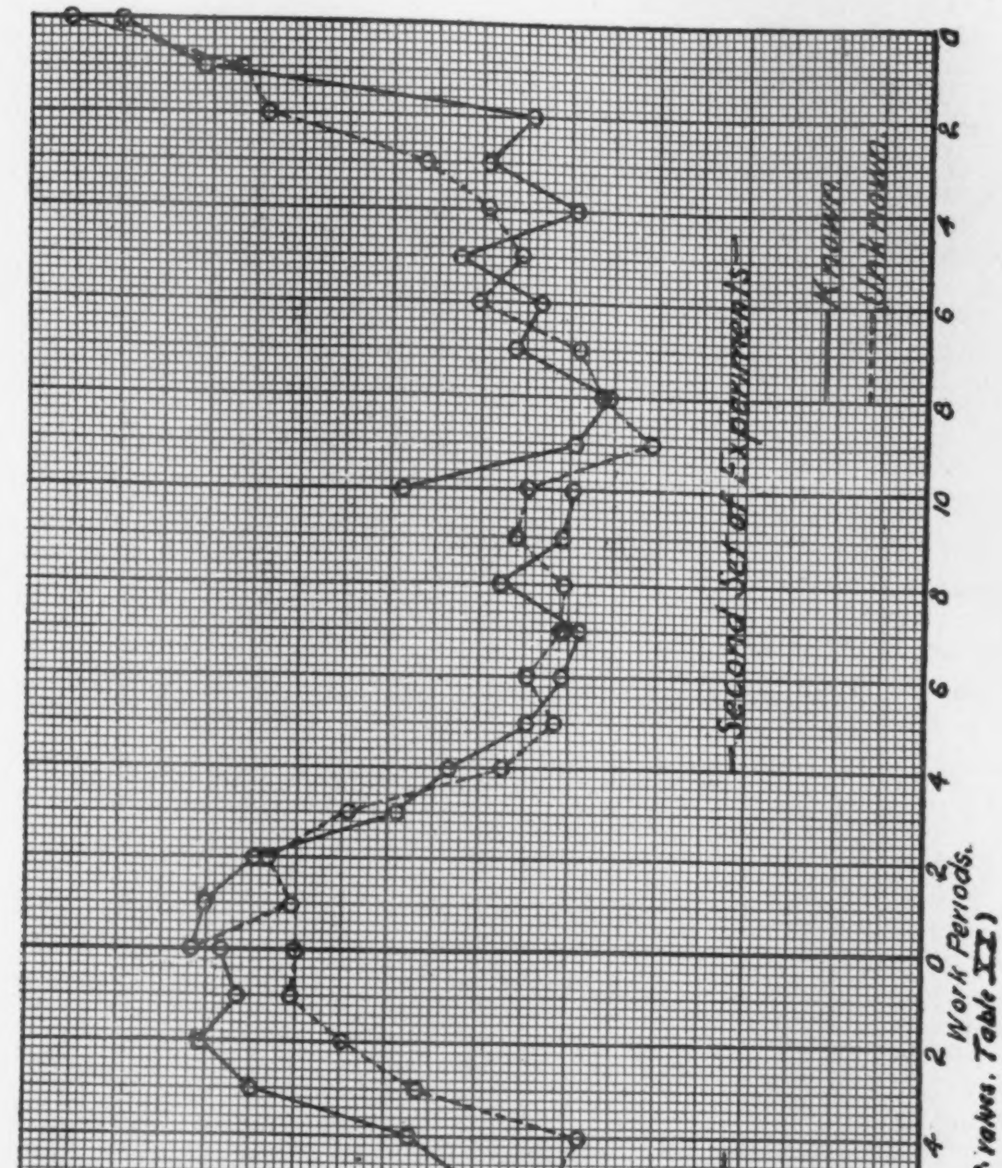
Curve 4. (MWJ values. Table XX.)

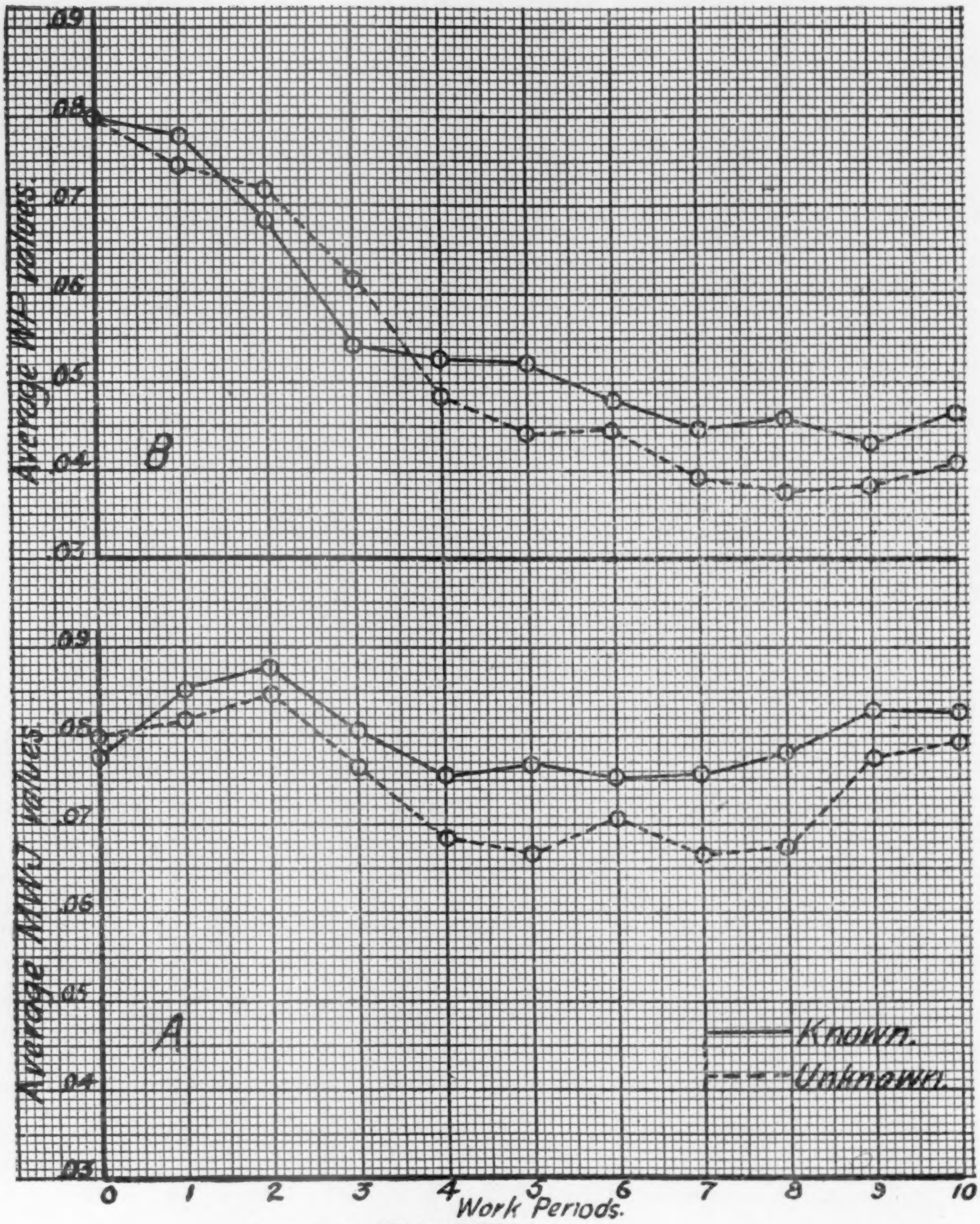
Table XX

Summary of Tables I to IX. With Respect to "W.P." and "M W J" Unit Values $(\frac{W}{C})$

Known Work Periods →	0	1	2	3	4	5	6	7	8	9	10
WP $\frac{\text{KgM.}}{\text{Sec.}}$ 1st Asc...	.0595	.0737	.0735	.0338	.0605	.0614	.0549	.0481	.0627	.0497	.0465
" " 1st Desc..	.0782	.0763	.0803	.0748	.0572	.0500	.0518	.0453	.0377	.0418	.0404
" " 2nd Asc..	.0816	.0800	.0747	.0586	.0532	.0446	.0404	.0383	.0474	.0409	.0397
" " 2nd Desc.	.0898	.0809	.0443	.0493	.0392	.0524	.0431	.0460	.0355	.0393	.0585
Average	.0795<	.0777	.0682<	.0541<	.0525	.0521	.0478	.0445	.0458	.0429	.0463
Unknown Work Periods											
WP $\frac{\text{KgM.}}{\text{Sec.}}$ 1st. Asc...	.0725	.0788	.0739	.0595	.0579	.0479	.0454	.0407	.0350	.0350	.0354
" " 1st Desc..	.0700	.0704	.0648	.0564	.0382	.0414	.0383	.0351	.0373	.0409	.0383
" " 2nd Asc..	.0817	.0704	.0731	.0641	.0473	.0414	.0446	.0410	.0404	.0459	.0448
" " 2nd Desc.	.0957	.0767	.0738	.0564	.0493	.0456	.0502	.0387	.0361	.0305	.0449
Average	.0797	.0741	.0714	.0616	.0482	.0441	.0446	.0388	.0372	.0381	.0408
Known Work Periods											
MWJ $\frac{\text{KgM.}}{\text{Sec.}}$ 1st Asc..	.0595	.0805	.0878	.0854	.0828	.0883	.0859	.0789	.0908	.0917	.0917
" " 1st Desc.	.0783	.0832	.0951	.0963	.0793	.0735	.0824	.0761	.0675	.0793	.0804
" " 2nd Asc.	.0820	.0875	.0883	.0750	.0726	.0663	.0625	.0679	.0844	.0864	.0785
" " 2nd Desc.	.0895	.0886	.0786	.0648	.0664	.0783	.0687	.0785	.0688	.0745	.0788
Average	.0773<	.0850	.0875	.0804	.0753	.0766	.0750	.0754	.0779	.0829	.0824
Unknown Work Periods											
MWJ $\frac{\text{KgM.}}{\text{Sec.}}$ 1st Asc..	.0705	.0893	.0876	.0747	.0707	.0714	.0708	.0677	.0624	.0658	.0692
" " 1st Desc.	.0713	.0768	.0759	.0723	.0662	.0612	.0608	.0627	.0669	.0803	.0814
" " 2nd Asc.	.0814	.0769	.0873	.0847	.0657	.0663	.0710	.0696	.0726	.0864	.0761
" " 2nd Desc.	.0957	.0842	.0879	.0736	.0710	.0672	.0799	.0656	.0648	.0768	.0896
Average	.0797	.0818	.0847	.0762	.0684	.0665	.0706	.0664	.0672	.0773	.0791
Av. Diff. between Kn. and Unkn. WP's	.0002<	*.0036>	.0032<	.0075<	.0043>	.0080>	.0032>	.0057>	.0086>	.0048>	.0055>
Av. Diff. between Kn. & Unkn. MWJ's	.0024<	.0032>	.0028>	.0042>	.0069>	.0101>	.0044>	.0090>	.0107>	.0056>	.0033>

* Sign > or < means that the known value is greater or less than the corresponding unknown value.


—First Set of Experiments—
—Second Set of Experiments—
—— Known
- - - - Unknown
Work Periods.
Curve 5.— (W.P. values. Table XI)
Kilogrammeters per second



Curve 6. (Table XX)

TABLE XXI

Summary of Tables I to IX and XII to XIX inc. With Respect to Absolute Values (W).

Known Work Periods	0	1	2	3	4	5	6	7	8	9	10
Absolute values	6.66	8.29	9.32	9.10	19.51	22.84	21.79	24.57	33.93	55.68	54.77
"	11.18	15.45	20.07	28.43	79.86	98.00	48.80	73.56	79.12	66.87	97.36
"	11.64	14.88	20.45	21.52	29.78	33.85	64.94	92.69	153.45	199.03	244.64
"	11.00	12.88	14.15	27.44	34.92	52.59	69.46	67.55	109.90	161.56	233.23
"	5.96	9.68	7.92	12.72	13.04	20.32	13.40	22.44	24.96	38.17	42.32
"	4.44	3.98	8.08	17.50	10.61	15.75	48.00	45.85	68.93	73.14	104.47
"	7.69	12.86	21.50	9.74	33.08	16.89	31.57	71.69	73.87	84.67	91.02
"	6.12	7.92	9.64	8.12	13.80	12.48	21.16	24.84	36.04	27.60	43.28
"	6.90	7.06	16.01	38.31	39.22	53.60	58.12	52.78	61.17	60.58	68.70
"	9.29	13.08	5.89	12.39	18.88	40.53	65.79	70.03	98.54	131.27	143.95
"	9.71	16.65	9.33	24.28	16.93	24.40	48.89	40.78	78.38	101.67	144.78
Average	8.23	11.16	12.94	19.05	28.15	35.57	44.72	53.34	74.39	90.20	115.04
Unknown Work Periods											
Absolute values	8.65	10.57	11.63	12.40	17.53	22.94	17.36	26.98	39.12	78.11	70.34
"	10.64	17.36	15.70	19.80	25.05	36.64	35.96	66.24	65.19	64.29	111.37
"	12.00	16.36	13.87	26.04	23.70	55.34	59.24	59.52	140.39	161.54	226.34
"	11.06	15.48	20.54	21.42	52.63	57.75	100.81	107.11	96.58	133.39	132.06
"	6.00	8.60	12.09	14.45	13.44	22.94	29.13	24.54	39.60	47.88	54.75
"	6.10	7.48	5.87	11.78	6.97	10.66	33.75	25.91	54.65	99.65	66.40
"	7.27	7.24	11.19	22.46	14.96	54.77	30.71	56.53	49.57	87.23	86.70
"	5.68	8.84	8.12	11.06	8.60	11.88	16.84	31.36	21.68	27.68	32.96
"	4.18	10.11	8.35	18.14	11.75	31.94	41.56	54.31	38.81	38.03	72.34
"	9.28	6.62	14.80	10.96	28.41	34.47	66.98	63.30	53.40	76.73	86.38
"	10.65	15.94	7.78	14.83	28.53	36.25	48.23	63.33	70.39	130.65	133.24
Average	8.32	11.33	11.81	16.66	21.05	34.14	43.69	52.65	60.85	85.92	97.53
Difference between Av. Kn. & Unkn. Absolute Values (W) and (>) greater or (<) less than unkn. values	.09 KgM. <	.17 KgM. <	1.13 KgM. >	2.39 KgM. >	7.10 KgM. >	1.43 KgM. >	.03 KgM. >	.69 KgM. >	13.54 KgM. >	4.28 KgM. >	17.51 KgM. >

TABLE XXII

Absolute (W) and Unit ($\frac{W}{c}$) Values	All Observers: Average W for Table I-VIII and XIII-XIX Inc. Kg M.	All Observers: Average $\frac{W}{c}$ for Tables I-VIII and XIII-XIX Inc. $\frac{\text{Kg M.}}{\text{Sec.}}$	All Observers: Relation of Av. Known of WP (Table XX) to Av. Unknown WP (Table XX)	All Observers: Relation of Av. Known MWJ (Table XX) to Av. Unknown MWJ values (Table XX)	Observer M: Average W for Tables IX-XII Inc. Kg M.	Observer M: Average W for Tables I-VIII Inc. Kg M.	Observer M: Average $\frac{W}{c}$ for Tables I-VIII Inc. $\frac{\text{Kg M.}}{\text{Sec.}}$	Observer M: Average $\frac{W}{c}$ for Tables IX-XII Inc. $\frac{\text{Kg M.}}{\text{Sec.}}$	Observer M: Average W for Tables I-XII Inc. Kg M.	Observer M: Average $\frac{W}{c}$ for Tables I-XII Inc. $\frac{\text{Kg M.}}{\text{Sec.}}$
Known Series	44.79	.0796	.0546 : .0526 $\frac{\text{Kg M.(1)}}{\text{Sec.}}$	.0796 : .0743 $\frac{\text{Kg M.(2)}}{\text{Sec.}}$	13.70	59.05	.0870	.2127	49.33	.1139
Unknown Series	43.95	.0743			12.30	53.05	.0824	.1347	44.36	.0936
Percent	.2	7–			10	10	5	35	10	18

(1) Amount of work done per second inclusive of the rest seconds.
(2) Amount of work done per second exclusive of the rest seconds.

the original load is followed by a corresponding increase in the rate of work seven times that of the original rate. That is, the loads are to each other as 2:3 while the corresponding rates of work are as 1:7.

Consideration of Curves

The six curves set forth the relationship of the unit values of the known work periods to the corresponding values of the unknown periods.

Curves 1, 2, and 3 show the relative individual unit efficiencies of each observer. Each of these curves is really made up of eight curves corresponding to the unit values of four known and four unknown series of work periods, excepting curve 3 which is made up of the efficiency unit values of three known and three unknown series. These curves show general agreement in that in the first set of experiments when the observer is aware of his progress he is strikingly more efficient than when he is ignorant of his progress. They also show that this difference is gradually overcome so that in the second set the advantage of the known series is not so apparent.

The general superiority of the efficiency values of the known work periods over that of the unknown is unequivocal for the various series of the first set of experiments. This is not true of the first two series of the second set of experiments as the three individual curves clearly show; it is still less true of the last two series of the second set. This interesting phenomenon is concomitant *with the appearance of imagery which seemingly parallels in function certain features of the mental complex operative for the known work periods.* A more complete discussion follows below.

The maximum advantage of a known work period over that of an unknown, in the case of observer M, is .0345 kilogrammeter seconds of work (Tables III and IV—4th work period, 4 seconds of rest); the maximum advantage of an unknown work period over that of a known is .0439 kilogrammeter seconds of work (Tables I and II). Obviously practice effects account for the superiority of the latter difference over the former (.0439

over .0345), since the zero work period of this series follows the tenth period of the known series. The corresponding values for observers W and J are .096 and .045 for the known and .016 and .038 for the unknown work periods respectively (Tables XIII, XVIII, XVII; curves 2 and 3). The enormous efficiency of observer W for the eighth work period of the first ascending known series and the low efficiency for the corresponding period of the unknown series remain unexplained.

The composite curves, 4 and 5 comprise the unit values found for the three observers. Curve 4 shows the relation of the unit values of the known and unknown work periods of all the series for all observers. That part of the curve which shows the relation of the unit efficiency values of the known and unknown work periods for the first set of experiments clearly indicates that "knowledge of results" is a favorable condition for work, for in this set, only four unknown work periods of the total number of periods (22 known and 22 unknown) exceed in efficiency their corresponding known periods.

The gradual appearance of the determining presence of imagery as a favorable condition in efficiency is evidenced by the fact that in the second set of experiments ten unknown work periods exceed in efficiency the known, while in the first set, as already stated, the unknown excelled the efficiency of the known work periods in four of the total periods of the set. Two and one-half times as many unknown work periods excel the known in the second set of experiments as in the first set. In two of the periods of this set the efficiency values of the known and unknown work periods are equal. These results when considered in conjunction with certain introspections given below, indicate that representative conscious factors in the unknown work periods of the second set of experiments possess the same *raison d'être* as the immediate conscious content present in the known periods of the same set.

In Curve 5, the seconds of rest are included in the efficiency values per unit of time. The character of the curve remains essentially the same as in Curve 4—practically unmodified by the inclusion of the rest seconds.

Curve 6 shows the average efficiency values per unit of time for all known work periods of all observers as compared to the corresponding unknown periods. Of curve 6, A shows the actual amount of work performed per second, i.e. at what rate the load was lifted. Part B of the curve shows the rate of work when the rest seconds are included. In one period (zero) only does the actual rate of work of the unknown period exceed that of the known. From A it appears that short rest periods of between one and three seconds are the most favorable and that medium rest periods of between four and eight seconds are the least favorable for maximum efficiency.

The Appearance of Imagery

The relation of the unit values of the known and unknown second ascending series of the second set of experiments is especially interesting in that the phenomenon of overlapping of the curves is concomitant with the appearance of imagery. From the introspections it appears that the condition of "ignorance of results" prevailed more completely in the first set of experiments than in the second set.

The approach of the values of the work periods of the unknown series of the second set of experiments to the values of the work periods of the corresponding known series is concomitant with the appearance of visual and kinaesthetic imagery. This imagery is reproductive of the perceptual experiences of the known period of the preceding series.

In the third work period of the second set of experiments, (Curve 1), the following introspection is recorded: "The task of this period proceeded with a fair degree of definiteness, with a comfortable degree of orientation hardly comparable to any of the preceding unknown periods. Certain individual lifts I pictured vividly; in certain other cases I compared successive lifts. The comparisons were especially pronounced when the first evidence of fatigue appeared." In the sixth period of the same series the observer remarked: "I seemed to sense the efficiency of the entire period in perspective more or less tangibly."

Imagery is also involved in the more or less abrupt close of the unknown period as contrasted with the gradual tapering off close of the known periods. On this point one of the observers remarks as follows: "In closing an unknown period I seem to let down suddenly in spite of all efforts to avoid it. Short lifts have little meaning in that I fail to image the pen marks which appear to support me in the long lifts."

In all these cases evidently the presence of imagery of the sort here described indicates that an effective condition for work prevailed. The presence of imagery was first detected in the first work period of the second unknown ascending series of the second set of experiments. It is interesting, as already noted, that the overlapping of the curves of this set of experiments is concomitant with the presence of imagery. As the imagery content of consciousness peculiar to the work periods of the unknown series approximates that of the perceptual content characteristic of the work periods of the known series, the differences in the awareness of results diminish. It is probable that the more essential features of the perceptual experiences acquired in the first set of experiments function in imagination in the work periods of the unknown series of the second set of experiments. If the mental complex present in the second set of experiments forms a close resemblance to that complex present in the first set, and, if the efficiency differences of the known and unknown work periods are primarily due to conditions indicated by the degree of "knowledge of results," then we have a clue for the crossing back and forth of those parts of the curves representing the unit values of the work periods of the second set of experiments (Curves 1, 2, 3, 4, 5).

The question may well arise as to why the values of the work periods of the known series do not approach those of the corresponding unknown series. Such an approximation would clearly be contrary to the law of habit. In general the normal work response is essentially perceptual in character; the particular ergographic work period in which the observer is aware of the details of his progress conforms to the normal procedure. The unknown work periods deviate from the normal procedure and

are therefore, less effective. The normal procedure involves a high degree of adaptation and, therefore, insists, as it were, that all allied deviates shall conform to its general mode of operation. This may explain why the values of the unknown work periods of the second set of experiments approximate those of the corresponding known values. The effects of the fully perceptual (known) procedure tends to drain the relatively non-perceptual (unknown) just in proportion to the extent to which the former have become habituated. Moreover, the perceptual response is normally more compelling and effective because more direct.

In the above event it appears that the presence of imagery is a mere indication that the non-perceptual has taken on the character of the perceptual procedure and this because the latter is the dominating mode of behavior.

From the general character of these curves and the introspective statements it appears that work carried on under conditions of partial awareness of results loses in efficiency and that such conditions are difficult, if not impossible, to maintain when followed or preceded by work of identical character under conditions of complete awareness. Without set purpose the observers experience certain mental complexes during work under the former conditions, which parallel certain essential features of the mental complexes present during work under the latter conditions.

Ergographic Records

A total of two hundred sixty-six records were taken of which nine typical ones are here reproduced. Five of these, (II, III, V, VIII, IX) record the efficiency of the observer when working under conditions of complete awareness of his accomplishment; the remaining four, (I, IV, VI, VII), likewise record efficiency but under conditions of relatively complete ignorance of results.

Seven of the nine records are given complete; Records VIII and IX have 164 and 230 subdivisions cut off respectively. The cut off subdivisions could serve no purpose here which is not already attained by the tabulated data. The reproduced parts of

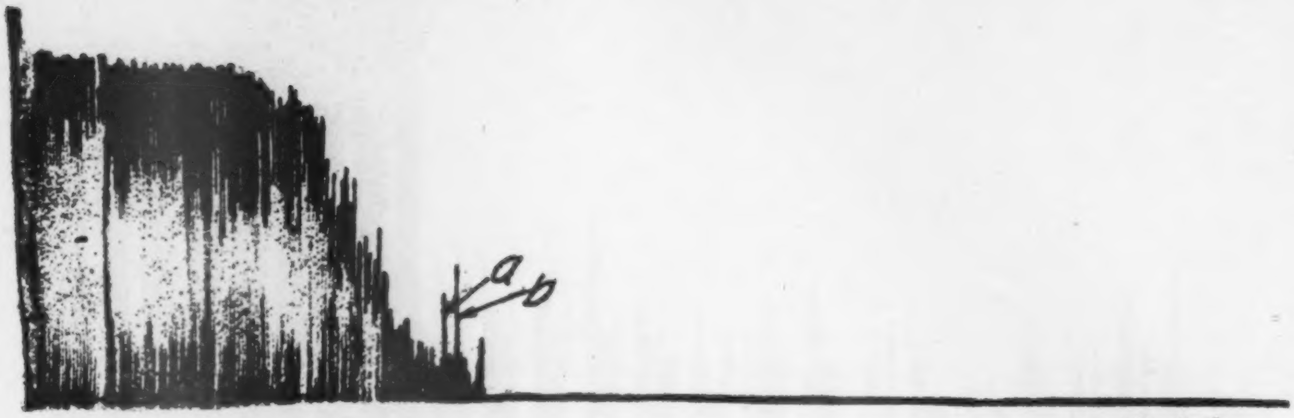
records VIII and IX, reveal what is important for our purpose here, viz., the characteristic close of work periods of extremely long duration. For the former record (See Table VII) the observer was in the machine 1 hour, 3 minutes and 49 seconds; for the latter, 1 hour, 27 minutes and 30 seconds.

(*a*) *The Phenomenon of 'Sudden Recoveries'*

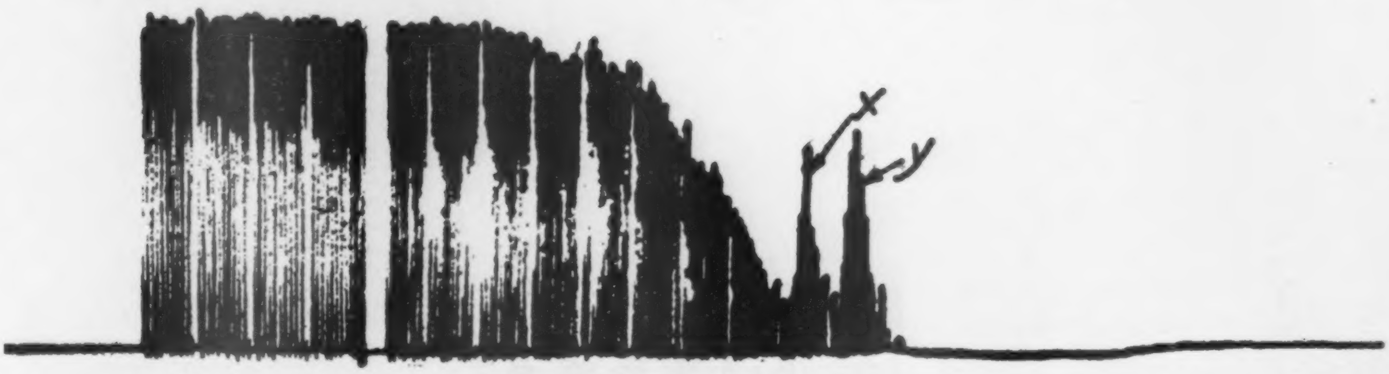
An examination of these records, particularly records VIII and IX, shows the very interesting and curious phenomenon of sudden and unexpected recoveries. In the subdivisions representing sudden recoveries the lifts were nearly as high as the lifts which were made in the earliest subdivision of the period. Reference to record VIII shows that three such recoveries are especially prominent: (1) A, including subdivisions 180 and 181; (2) B, subdivisions 186 to 192 inclusive; and (3) C, subdivision 196. The same phenomenon is probably found in record I at lifts marked "a" and "b"; in record II at "x" and "y." It is not improbable that a definite ratio exists between the frequency and extent of these sudden increases in efficiency and the duration of the work period.

It should be recalled at this point that the observer was instructed before the beginning of each work period and occasionally reminded during the progress of the period that each lift must represent maximal effort. It can not be maintained therefore that the subdivisions following 181 and preceding 186, for example, afforded an opportunity for rest as their efficiency values would seem to indicate. In fact, these subdivisions (182-185 inc.) are among the most laborious of the entire period. The statements below make it difficult to explain the phenomenon in such easy fashion as 'increase of attention to the work' or 'mechanical imperfection in the apparatus.' The phenomenon is found frequently in periods of very long duration and for all observers, but it is not equally prominent for all observers nor in all the periods of a given observer (Record VIII and IX). Schenk[7] seems to have obtained an aberrant fatigue curve when the work period covered one hour. It is doubtful

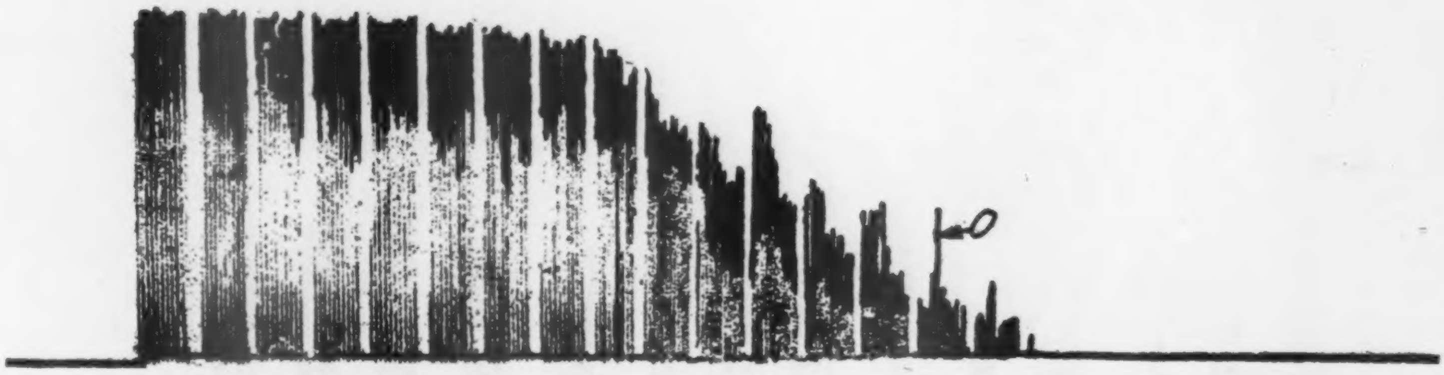
[7] Archiv. f. d. ges. Physiologie, 1900.
[8] Amer. Jour. of Physiology, Vol. V, p. 248.
[9] Amer. Jour. of Psychology, Vol. III, pp. 25, 26.



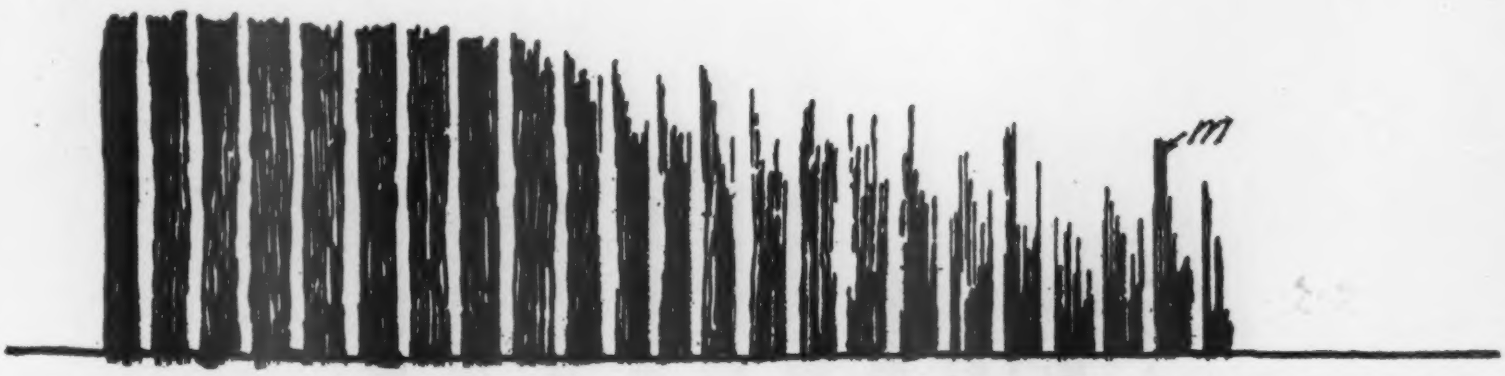
Record I. Unknown Series. No Rests. $\frac{W}{C} = .087 \frac{KgM.}{Sec.}$



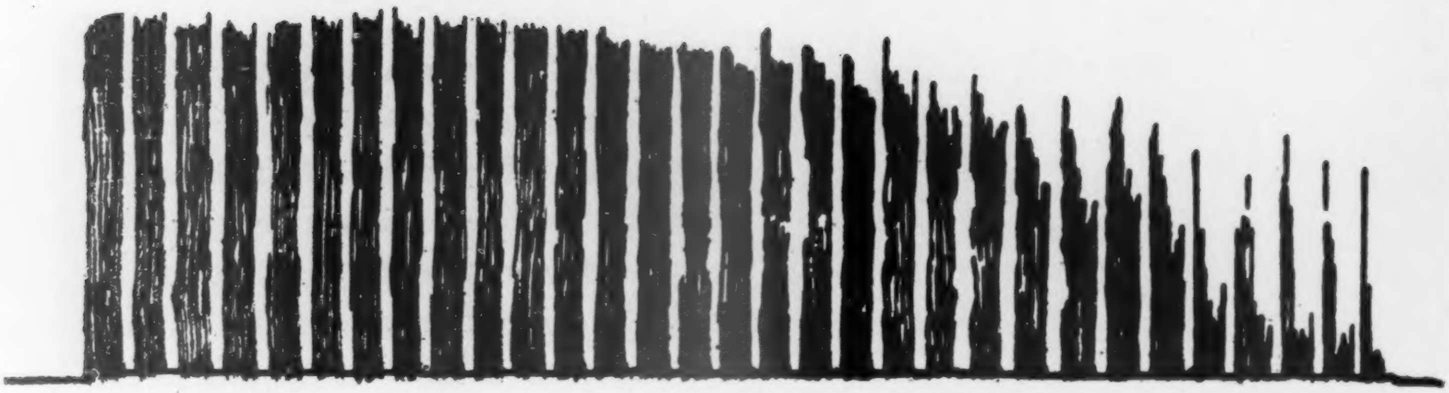
Record II. Known Series. 1" Rest to 10" Work. $\frac{W}{C} = .091 \frac{KgM.}{Sec.}$



Record III. Known Series. 2" Rest to 10" Work. $\frac{W}{C} = .087 \frac{KgM.}{Sec.}$

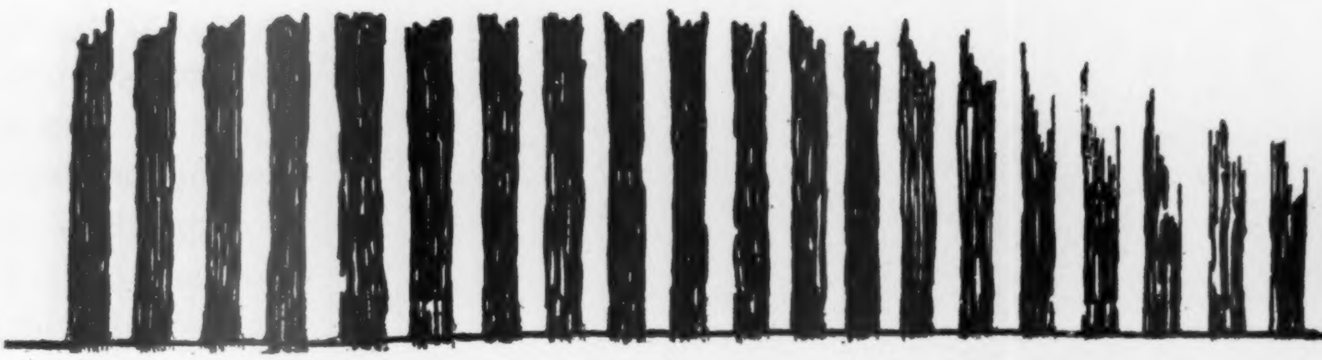


Record IV. Unknown Series: 3" Rest to 10" Work. $\frac{W}{C} = .080 \frac{KgM}{Sec.}$

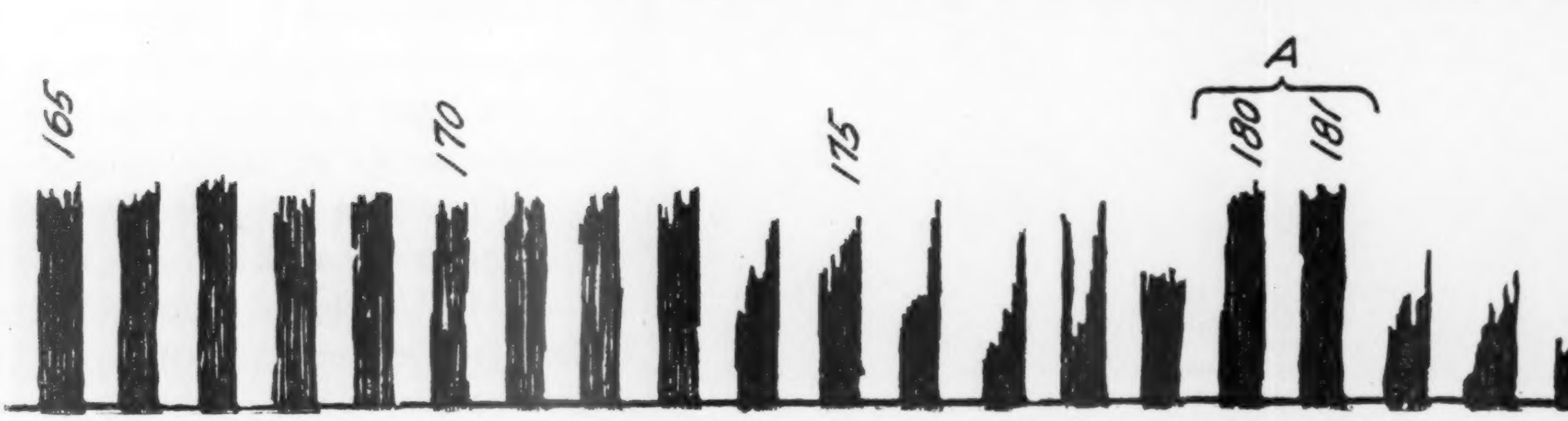


Record V. Known Series. 4" Rest to 10" Work. $\frac{W}{C} = .098 \frac{KgM}{Sec.}$

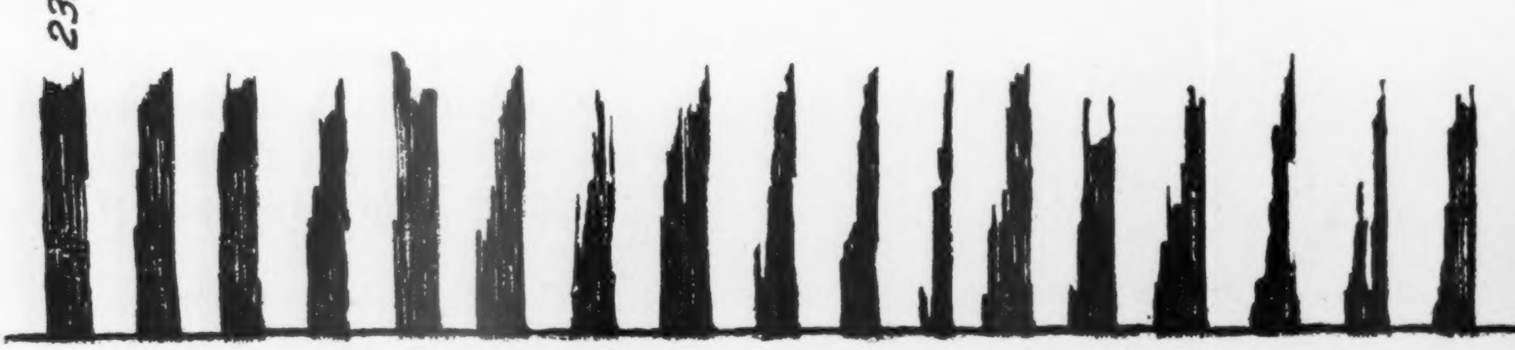
Record



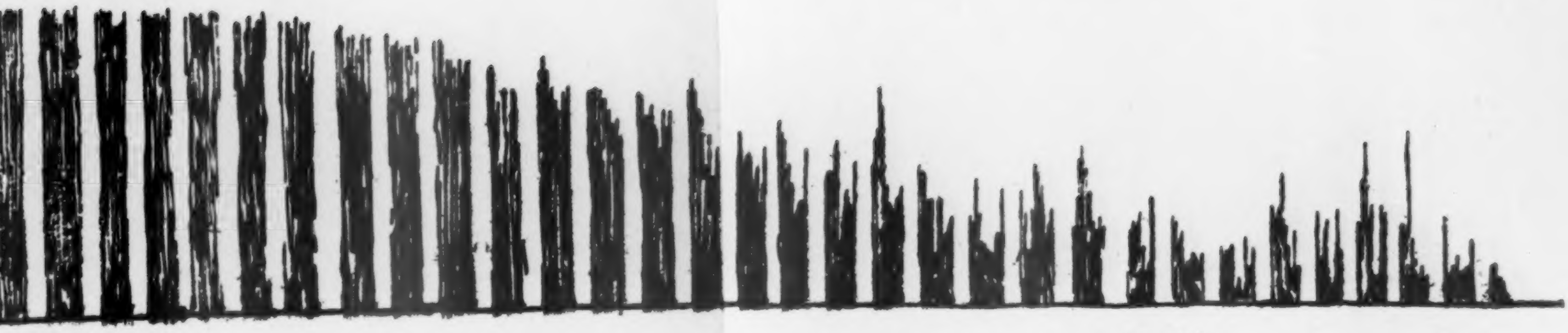
Record VII. Unknown Series. 7" Rest to 10" Work. $\frac{W}{C} = .06$



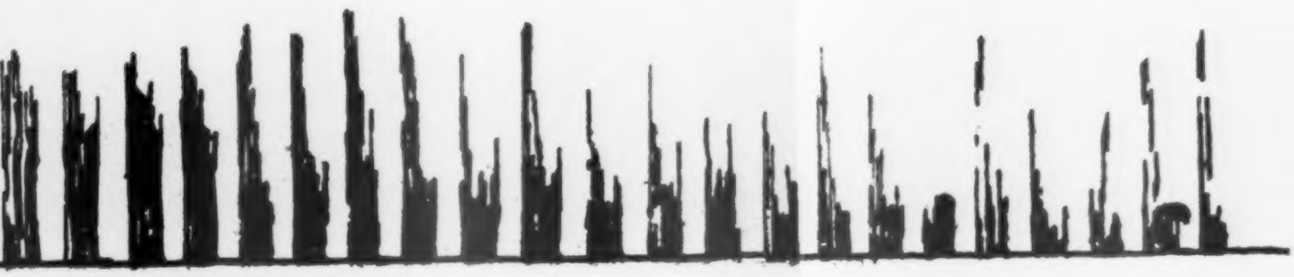
Record VIII. Known Series. 9" Rest to 10" Work. $\frac{W}{C} = .080 \frac{KgM}{Sec.}$



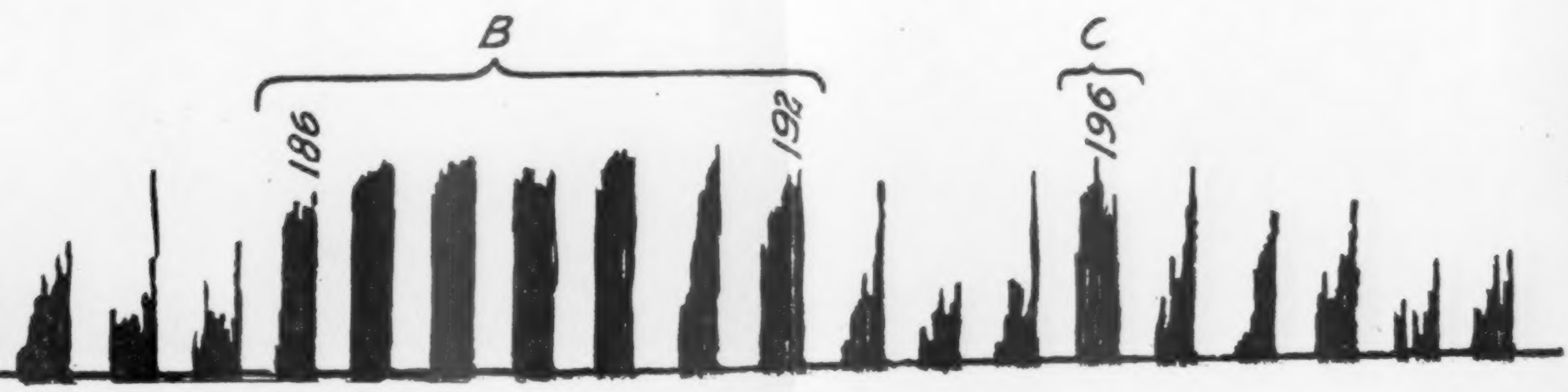
Record IX. Known Series. 10" Rest to 10" Work. $\frac{W}{C} = .092 \frac{KgM}{Sec.}$

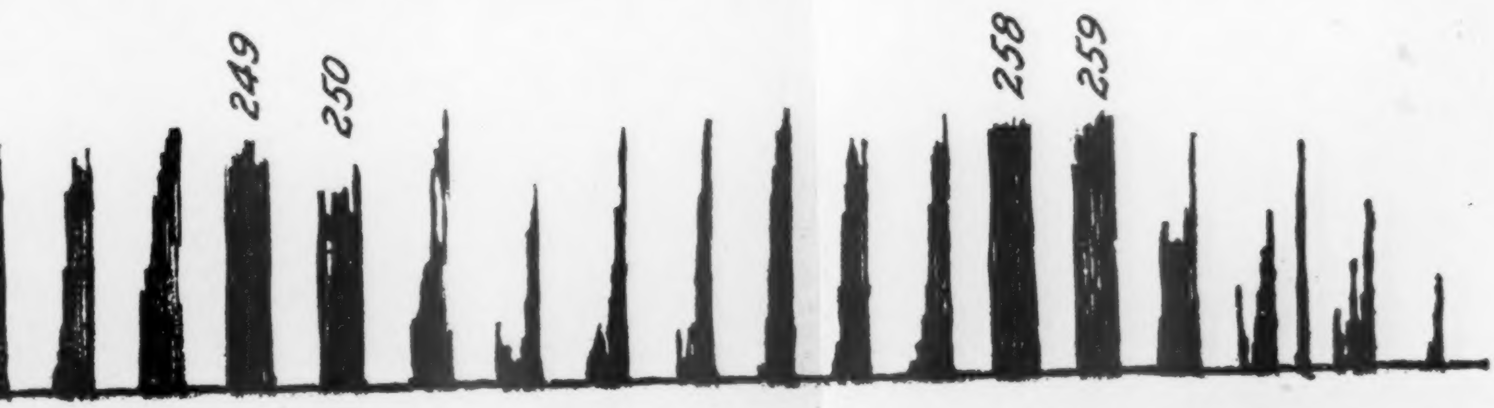


cord VI. Unknown Series. 5" Rest to 10" Work. $\frac{W}{C} = .070 \frac{KgM}{Sec.}$



$= .068 \frac{KgM}{Sec.}$





$\frac{KgM}{Sec.}$

whether fatigue curves of short or long duration are ideally asymptotic as Hough[8] maintains.

The work of Lombard[9] has so direct a bearing upon the 'phenomenon of sudden recovery' that I take occasion to quote him at length. He lifted a weight of three kilograms by the flexor muscles of the second finger of the left hand every two seconds until exhausted. "Each contraction was the strongest possible" and "I was determined to fatigue the muscles so completely that no contraction should be possible. After 110 seconds of continuous work, I could *hardly stir* (italics mine) the weight, and thought the experiment nearly at an end. *To my surprise* (italics mine), however, I began to recover the lost power, and during the next half minute each of the succeeding contractions was higher than the one which had preceded it. The effect of fatigue then began to manifest itself again, and the contractions became smaller. I concluded that I had made a mistake, that I had not exerted all my will power before, and I determined for the rest of the experiment to do my best. As the contractions grew smaller I threw all my power and energy into each attempt to raise the weight. I was conscious . . . that my face was flushing under the strain; nevertheless, the contractions became gradually less, and I supposed that I had finally succeeded in tiring out the muscles, when, *to my astonishment* (italics mine), I began to recover my power a second time. The contractions became stronger, reached a maximum and fell, only again to recover. In short, for some inexplicable reason . . . the ability to voluntarily contract the muscles with sufficient strength to raise the weight, decreased and recovered five times." These statements are interesting and take on added significance when compared with the statements of observer M given below.

Lombard[10] believes the phenomenon constant and normal and that it appears "after considerable work has been performed."

With regard to these sudden and unexpected recoveries Observer M remarks as follows: "During subdivisions 182 to 185 inclusive I experienced a sharp pain unlike anything previously experienced. It disappeared quite suddenly at the beginning of

[10] Ibid., p. 30.

186th subdivision. For the next six subdivisions my experience was most unusual. My finger seemed detached and lifting of its own accord, apparently without any effort on my part and with an indescribable sense of exhilaration. I seemed to be beginning all over again except that I seemed to have no part in lifting. The recovery was sudden, unexpected and as though something had been cut loose. At these times the lifts were uncontrolled while I seemed nothing more than an interested spectator."

The phenomenon here described is not confined to records VIII and IX but is observable in most of the long and many of the short records, as the introspections show. For subdivision 258, Record IX the following introspection is recorded: "I seem to begin all over again except that the feeling of effort incidental to initial action is lacking and I enjoy a peculiar sense of ease and agreeableness. Strain and tension for the time being disappear while the muscular mechanism functions almost automatically. The conscious correlate so far as it may be considered "causal," subsides almost to the vanishing point. At these times the 'will' seems to have very little to do with the lifting. This is interesting in view of the fact that the periods, especially those of long duration, are extremely disagreeable due to the condition of the experiment, viz., that each lift must represent maximal voluntary effort. The attentive strain is enormous."

(*b*) *Interpretation of 'Sudden Recoveries'*

There is no accounting for this phenomenon on the ground of greater determination or a stiffening resolution, for each lift, according to the conditions of the experiment, represents maximal effort. A plausible explanation may be found in the assumption that certain efferent neurones are serially related to particular muscles or groups of muscles. Within a group we may assume a serial arrangement of neurones of constantly diminishing functional efficiency. The number of neurones in the group, their order of efficiency and their functional appearance are probably indicated by the recovery periods on the ergographic records. It seems that action over a given set of neurones does not exhaust the energy of the muscles with which the neurones are connected but that continued innervation by means of these neurones is followed by increasing impermeability of the motor end-organ. If

now the cerebral line of discharge takes place over a different set of neurones the link between neurone and motor end-organ again becomes permeable. Points marked "A," "B" and "C" on Record VIII may be regarded as reestablished points of permeability. Following this hypothesis exhaustion appears when the junction between the cerebro-muscular chain can not be maintained.

Whether impermeability is a result of cerebral or peripheral fatigue or both is a question not yet finally settled.[11] Lombard,[12] it may be mentioned, conducted a series of experiments which lead him to believe that the sudden recoveries (periodic variations) are of "central rather than peripheral origin." With reference to these experiments he says: "These and other similar experiments convinced me that the changes producing the periodicity, do not occur in the nerves, the nerve ends, in the muscles, and that they take place in the central nervous system." Moreover, he believes that the phenomenon of periodicity is distinctly connected with voluntary contractions since periodicity (sudden recoveries) fails to appear when the muscles are electrically stimulated.

McBride[13] seems to confirm Lombard in that central fatigue is the important factor which finally terminates the work. It seems to be quite generally agreed that the point of voluntary inefficiency is only secondarily related to peripheral fatigue.

Weichardt[14] holds that the body in the course of its diurnal activity developes an antitoxin against fatigue-products which are rendered, at least partially, ineffective. If such toxins are actually present we may find a plausible explanation for the phenomenon of 'sudden recoveries' (A, B, C, Record VIII) in the periodic rise in efficiency of the toxins.

Our fatigue records (I to IX, or any fatigue curves) may then be regarded as to some extent records of the interaction of the two kinds of toxins. These must be regarded with respect

[11] Storey, T. A., in the Amer. Jour. of Physiol., Vol. 8, p. 373 and Lee and Everingham in Am. Jour. of Physiol., Vol. 24, p. 384 give the important literature concerning the seat of fatigue.

Abelous, J. E., Contribution a l Etude de la Fatigue, Arch. de Phys. 1893, 3.

[12] Ibid., pp. 30-35.

[13] Journal of Nerv. and Mental Diseases, 1901, p. 628.

[14] Mun. Med. Wochenschrift, 1904 and Weber Ermudüngstoffe, 1910.

to function as antagonistically related. In these circumstances the fatigue-toxins and their antitoxins are negatively and positively related to muscle respectively. Work periods 249, 250, 258, 259 in Record IX represent periods of special effectiveness of the antitoxins. Such periods are again indicated by "a" and "b," in Record I; "x" and "y" in Record II; "o" in Record III; "m" in Record IV.

That the phenomenon of periodicity (recoveries) is one not exclusively connected with voluntary contraction seems conclusively established by Storey[15] and others. Instead of voluntarily stimulating human muscle he employed graded increases in the strength of an induction current. The subdivision intervening between 173 and 180; 181 and 186 and between 192 and 196 in Record VIII may be regarded as constituting Storey's "intervals of lower contractions." This phenomenon had previously been observed by a number of German investigators[16] in experimenting with muscle-nerve preparation from the frog.

SUMMARY

1. Within the limits operative for the present study both the absolute amount of work and the rate of work done under conditions of knowledge of results exceed that done under conditions of ignorance of results. The two sets of conditions do not maintain the same degree of discreteness throughout the entire duration of the experiment. As the latter conditions, indicated by reproductive imagination (see "3" below), approximate the former conditions, the relation of the work value becomes ambiguous. (Curve 1, second set of experiments).

Will power as conventionally regarded is inadequate to explain the efficiency differences. It is more likely that the neuro-muscular chain underlying the lifting response functions more efficiently when the afferent channels from the eye are open than when they are closed. The former condition appears provocative of greater functional changes in the central nervous system than the

[15] Am. Jour. of Physiol. pp. 439, 440. The important literature on the phenomenon in question is cited in this reference and need not be reproduced here.
[16] Ibid.

latter, which changes operate to maintain attention and increase muscular efficiency.

Attention may well be a "disinterested spectator" and a mere sign for the degree of central functional changes which become determinants of the efficiencies of the various work periods. Habituation to maximum voluntary effort under the two conditions of the experiment would probably reduce to a minimum the efficiency difference apparent for the two sets of conditions. In other words, efficiency differences probably represent degrees of the process of habituation.

2. When work is long continued and to the point of exhaustion a curious phenomenon of sudden recovery appears which can not be entirely identified with phenomena peculiar to fatigue. This phenomenon is especially pronounced in work periods of extended duration. Such sudden fluctuations in efficiency find a plausible explanation in a functional grouping of the neurones connected with the group of muscles involved in lifting the ergographic load.

3. The condition of 'ignorance of results' is more effective in the first set of experiments than in the second set. In the latter set imaginative elements, in the unknown series of experiments, parallel the perceptual elements in the known series of the same set. The ambiguity of the efficiency values obtained under the two sets of conditions for the second set of experiments may be regarded as an interesting stage in the process of habituation.

4. An increase of the ergographic load by 2 kilograms decreases the variations in the amount of work done in successive work periods and, such increase does not essentially affect the conclusions drawn from the first and second sets of experiments.

5. The optimal rate of work under the conditions of the experiment lies between .075 and .085 $\frac{\text{Kg M.}}{\text{Sec.}}$

6. The commonly observed staircase (Bowditch "treppe") contractions appear irregularly and for the most part in the closing subdivisions of a work period. This is probably due to the fact that each lift represents maximal contraction and that each lift is negotiated by muscles thoroughly trained.